Post Construction Stage Geotechnical Investigation of Idamalayar Hydro Electric Project Idukki District, Kerala

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Abstract

Post Construction stage geotechnical investigation was taken up to assess the cause and extent of the reported leakage in the intermediate inspection gallery, near construction block joint of 15 & 16, at Ch. 436m. Initially, it was apprehended by the project authorities that the probable reason for the seepage could be the shear zone in block 16, which coincide with the fault trace in the foundation. But, the inspection of the site revealed a different picture and is dealt briefly in this paper.

The Idamalayar Hydro Electric Project comprises a 373 m long concrete gravity dam of about 102.4 m height (from the deepest foundation level), constructed across Idamalayar River, at Ennakkal, Idukki District, Kerala. The dam foundation rests on hard and massive charnockite/gneiss, beset with minor shears/fault and joints. The foliation dips into the flanks there by suggesting an antiformal valley, with the river flowing along the axis of the fold. The rock is cut across by 6 sets of joints of which foliation joint set is prominent.

A transverse gallery has been provided, from main drainage cum foundation gallery at about 2 m left of the shear zone In addition, two more longitudinal galleries, at the middle and toe area of block 12 and 16, are provided. Two reliefs wells/reinforced shafts were also provided, in block 16 across the shear zone. Upon inspection of lower inspection galleries (3 nos. parallel to one another) near construction block joint of 15 & 16, at Ch. 436m and the transverse gallery, no leakage could be observed in any of the block joints or in their vicinity. Inspection of the gallery, at the location of shear zone revealed absolutely no seepage from the shear zone section. Ironically, while there is no seepage in the lower inspection galleries, above the block joints 15 & 16, coinciding with the trace of shear zone, significant seepage has been reported from the middle inspection gallery. No signs of wall deformation and development of cracks justifying differential settlements in the shear zone section could be observed. It is, therefore, evident that the reason for the leakage reported in the middle gallery is not due to the shear zone or due to any other geological reasons.

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The seepage and the dam water level were analyzed and the results indicated, that the seepage stopped while the water level goes down to the level of intermediate gallery, i.e., 128.50 m. Therefore it was concluded that, the reason for seepage in the intermediate gallery is due to damage in the construction joint, between block 15 & 16 and not due to any geological factor. The copper strip provided to seal the construction joints might have been corroded, giving way to the dam water to seep through from u/s face of the dam along the construction joint. Admist, it was found that most of the shaft drains got chocked due to calcinations and failed to channelise the water. It is also, presumed that the water trapped within the shaft drains have found a passage through the block joints. Measures like reaming of chocked drains and grouting of leakage loci during the lean season have been recommended.

1. Introduction:

Idamalayar Hydro electric Project comprises a 373 m long concrete gravity dam of about 102.4 m height (from the deepest level) at Ennakkal, constructed across Idamalayar River. It has 1564 m long Head Race Tunnel ending in an 89.116 m high Surge Shaft and 858 m long surface penstocks (two nos.) descending to the surface power house of capacity 75 MW (37.5 MW x 2 nos.). Geotechnical investigation was carried out at the Idamalayar Dam, for the reported leakage in the intermediate gallery, near construction block joint 15/16 besides an inspection of the dam and its vicinity.

2. Geological Framework:

2.1 Regional Geology:

Geologically, the rock types in this region can be classified into Peninsular Gneissic Complex , Migmatitic Complex, Charnockite Group and Khondalite group of rocks, besides, Quaternary sediments spread along the western coastal tract.

The Peninsular Gneissic Complex, represented by granite gneiss is the oldest rock in the area. It is foliated and invariably involved in folding. Khondalite group of rocks are largely spread in the southern part. These rocks also occur as linear bands, lenticular bodies or enclaves mostly within the gneissic terrain. Charnockite is the predominant rock type in the Charnockite Group, while pyroxene granulite and magnetite quartzite have a lesser spread. Charnockite mostly occurs as a massive rock, though gneissic variants, of intermediate to acidic composition, are observed at many places. The Migmatite Complex comprises of biotite gneiss and hornblende biotite gneiss (Composite Gneiss).

Regional trend of foliation is highly variable between N-S and WNW – ESE, with gentle to moderate dips on either side. The rocks have been subjected to three phases of folding as a result of compressional forces.

2.2 Structure & Seismotectonic:

Large parts of Idukki and adjoining districts of Kerala forms part of a well defined tectonic domains in the southern peninsula, the Pandiyan Mobile Belt with granitoid massifs and Charnockite towards north and the Khondalite belt towards the south. The area is generally regarded as a 'Stable Continental Region' (SCR), in the context of earthquake occurrences, though occasional mild seismicity is reported since historical times. Geologic and geodetic expression of active deformation is limited. However, the SCR is traversed by numerous faults/mega lineaments (Drury et al.1984; Katz, 1978). Several dike swarms and acid igneous bodies of varying ages occur either along or sub-parallel to these lineaments or faults.

The major lineaments trends observed in the region include the NW-SE, NE-SW, NNW-SSE and WNW-ESE trending sets. Geological data suggests that majority of these lineaments representing the fracture systems/faults, are of Precambrian origin, while a few lineaments are possibly of neotectonic origin and do not relate to Precambrian tectonic events.

The striking linear drainage, disposed in NNW – SSE direction from Perumuzhi to Kuttampuzha, denotes that the river course is following a linear structural feature, joint or fault plane. The dyke rocks are emplaced parallel to this lineament. The unmetamorphosed Idamalayar gabbroic dyke with a NNW-SSE trend is traced for over 80 km in the central part of Kerala.

2.3 Geology of the Project Site:

The dam is founded on a country of migmatised charnockite gneiss, intruded by dolerite and gabbro dykes, which in turn are cut across by pegmatite and quartz veins (Plate 4). The left flank is occupied by mainly charnockite whereas, the right flank is occupied by granite gneiss. The rocks on the left flank are comparatively massive and less disturbed than the right flank (Rajagopalan, & Srinivasan, 2006). The regional foliation is trending N 40° to 70° W – S 40° to 70°E direction dipping 40° to 75° towards N 30° - 50° E. The foliation dips into the flanks there by suggesting an antiformal valley, with the river flowing along the axis of the fold. The rock is cut across by 6 sets of joints viz.,

i) N 10° W – S 10° E to N 30° W – S 30° E dipping 70° towards SW
ii) N 10° E – S 10° W to N 25° E – S 25° W with vertical dip
iii) N 55° E – S 55° W dipping 70° towards S 35° E
iv) N 30° W – S 30° E dipping 40° towards S 60° W
v) N 70° W – S 70° E dipping 80° towards N 20° E
vi) N – S dipping vertically

3. Back ground information:

Dinkar Srivastav, (F.S.1982-83) and G.Rajagopalan, (F.S.1980-81), carried out foundation mapping of the dam and described that it consists of 22 monolithic blocks, out which blocks 1 to 8 are founded over the migmatised charnockite and granite gneisses, which are relatively less jointed. In Blocks 9 to 15, the rocks are closely jointed/ fractured, gabbro dyke, dolerite with xenoliths of charnockite gneiss. The xenoliths of gneissic rocks aligned sympathetic to the river lineament had sheared contacts displaying narrow, clay gougy zones which were provided dental treatment. Block 16 is occupied partly by dykes and partly by shear zone of average 2 m width and is intensively fractured and crushed. Extensive treatment had been provided to the area lying between blocks 12 and 16 based on the permeability and poor bearing capacity values. In view of the shear zone, traversing the foundation from u/s to d/s , a transverse gallery, from main drainage cum foundation gallery at about 2 m left of the shear zone, to the toe in block 16 , has been provided for drainage and treatment, for future needs. In addition, two more longitudinal galleries, at the middle and toe area of block 12 and 16, are provided. Two reliefs wells/reinforced shafts, in block 16 across the shear zone, were provided to increase the path of percolation. The blocks 17 to 22 are abutted against the steep slope of the right bank

4. Geotechnical Evaluation:

Post construction geotechnical investigation was carried for Idamalayar Dam, for the reported leakage (at ch.434m), in the middle inspection gallery, near construction block joint of 15 & 16, at Ch. 436m (Photograph 2a & 2b). Initially, it was apprehended by the project authorities that the probable reason for the seepage could be the shear zone in block 16. But, the inspection of the site revealed a different picture. The observations and inferences are discussed below.

4.1 Inspection of Shear Zone:

Initially, inspection was made in the lower galleries in block 15 and 16, where the shear zone was reported in the foundation. All the three lower inspection galleries (parallel to one another) and the transverse gallery were carefully inspected and no leakage could be observed in any of the block joints or in their vicinity. Inspection of the galleries, at the location of shear zone (picture 1a) revealed absolutely no seepage from the shear zone section, except from the foundation drains and the release wells. Ironically, while there is no seepage in the lower inspection galleries, above the block joints 15 & 16, coinciding with the trace of shear zone, significant seepage has been reported from the middle inspection gallery. No sign of wall deformation and development of cracks justifying differential settlements in the shear zone section could be observed. It is, therefore, evident that the reason for the leakage reported in the middle gallery is not due to the shear zone or due to any other geological reasons.

4.2 Leakage in Intermediate Gallery:

The leakage and the dam water level recorded over a period of 36 days has been listed date wise in the Table 1. The leakage ranges between 10.6 LPM and 23.58 LPM. A graphical plot of water level Vs leakage (Figure 1) shows that, there is no correlation of leakage and the fluctuation in the dam water level. A significant observation was that, initially there was a gradual increase in seepage which came down to 10.6 LPM on

3.10.11. Suddenly, there was surge in the leakage from 5.10.11 onwards and which reached maximum (23.58 LPM) on 10.10.11, thereafter gradually reduced and stabilised around 20 LPM. After analysing the total seepage data accumulated over the years, it is observed that the maximum total seepage so far recorded is 110.54 LPM in September 1994. As against this data, presently, the total seepage is of the order around 68 LPM only.

Picture 1 Photograph showing faces of different drainage galleries; a. Dry face in the shear zone in the Lower drainage gallery ; b, c, d. – dry faces of three lower drainage gallery parallel to one another in the construction block joint 15/16

Table 1
Leakage and Dam Level

S.No.	Date	Leak in LPM	Water Level m
1.	24.9.11	13.3	168.66
2.	25.9.11	14.44	168.68
3.	26.9.11	14.44	168.68
4.	27.9.11	14.3	168.66
5.	28.9.11	14.3	168.64
6.	29.9.11	12.85	168.62
7.	30.9.11	12.85	168.6
8.	1.10.11	12.85	168.56
9.	2.10.11	11.78	168.52
10.	3.10.11	**10.6**	168.48
11.	4.10.11	**10.6**	168.44
12.	5.10.11	18.4	168.4
13.	6.10.11	20.2	168.34
14.	7.10.11	22.13	168.28
15.	8.10.11	22.81	168.22
16.	9.10.11	23.32	168.16
17.	10.10.11	**23.58**	168.08
18.	11.10.11	23.45	168.04
19.	12.10.11	23.4	**168.98**
20.	13.10.11	21.6	168.96
21.	14.10.11	20.7	168.92
22.	15.10.11	20.83	167.88
23.	16.10.11	20.48	167.86
24.	17.10.11	20.06	167.8
25.	18.10.11	20.56	167.82
26.	19.10.11	20.3	167.8
27.	20.10.11	19.9	167.77
28.	21.10.11	20.4	167.74
29.	22.10.11	20.4	167.72
30.	23.10.11	20.84	**167.66**
31.	24.10.11	19.72	167.71
32.	25.10.11	18.54	167.73
33.	26.10.11	18.52	167.71
34.	27.10.11	17.94	167.78
35.	28.10.11	20.16	167.82
36.	29.10.11	19.35	167.79

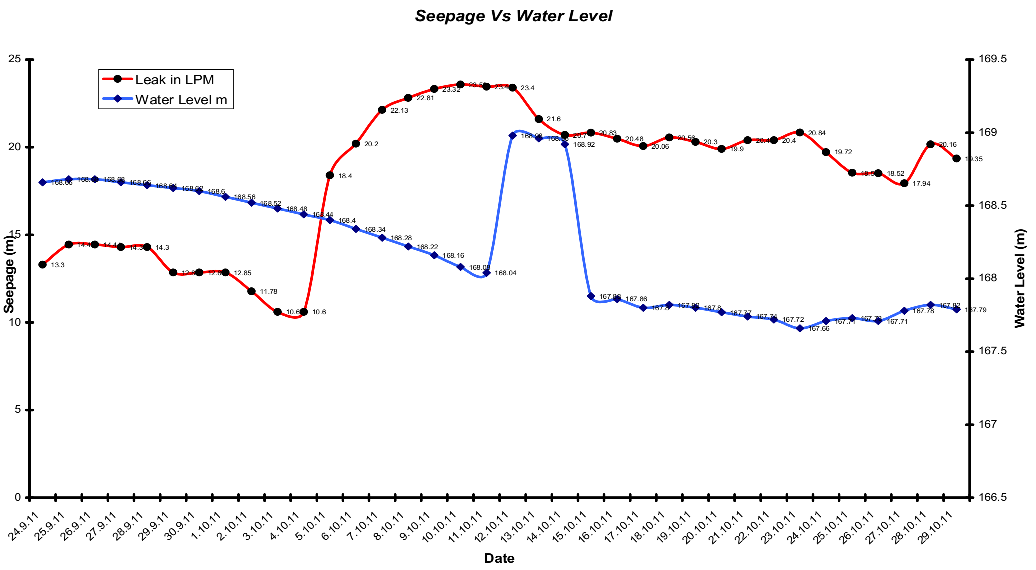


Figure1 Graph representing Leakage vs Water Level

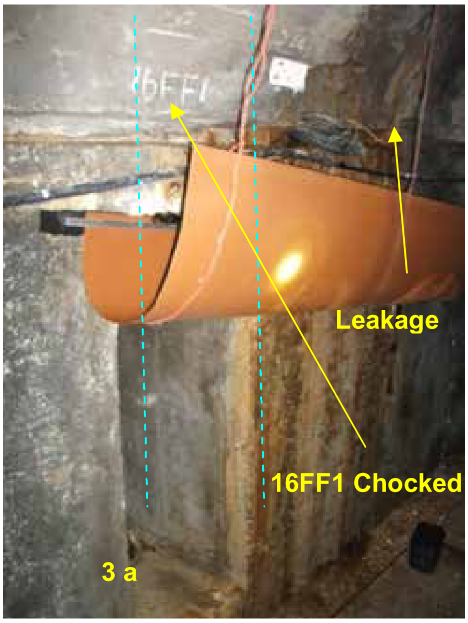
Picture 2 Photograph showing leakage at ch.434 m in intermediate drainage gallery; a. leakage in block joint 15/16; b. Photograph showing the proximity of chocked formed drain to the leakage point in block joint 15/16

4.3 Formed Trap Drains:

In spite of the provision of water stops, there may be leakage through the body of the dam due to the pressure of water from the upstream. In order to remove this water, vertical formed drains (10 inch dia) have been provided to trap the seeping water through the contraction joint. They are not only provided at the transverse contraction joint, between two adjacent blocks of concrete gravity dam, but are even placed at an equal interval of about 3metres centre to centre, staggered in all blocks, as recommended by the Bureau of Indian Standard, code IS:10135-1985 "Code of practice for drainage system for gravity dams, their foundations and abutments". The formed drains have an opening in the intermediate gallery and continue further down and to convey the drainage water to the lower drainage gallery and from there it is pumped out.

Most of the formed trap drains were found partially chocked and in some cases completely chocked due to calcinations (pictures 3a & 3b). This was observed near the block joint 15/16, viz. 16FF1, 16FF2, 16FF3 and 15FF4 and so on.

It is, thus presumed that, the copper strip provided to seal the construction joints might have corroded, giving way to the dam water to seep through from u/s face of the dam along the construction joint. Most drains got chocked due to calcinations and failed to channelise the water. Due to chocking of the formed drains, the seepage water has accumulated inside the contracted formed drains, leading to formation of local hydrostatic head. In this case, since there is a blockage, the seepage water has found its path in the block joint 15/16, in the intermediate gallery near ch.434m.



Picture 3a. Chocked Formed Drain 16FF1 opening in intermediate gallery;
Picture 3b. Leakage water could not pass further down through 16FF1 formed drain due to chocking

5 Conclusion:

No wetting or seepage has been observed in any of the faces in the lower drainage galleries. But, most of the formed drains are chocked due to calcinations. Significantly the formed drain no.16FF1 near the leakage point in block 15/16 is completely chocked at the opening in the intermediate drainage gallery. No signs of wall deformation and development of cracks justifying differential settlements could be observed, which suggests that there is no link between with any geological feature and the leakage at ch.434, in the intermediate drainage gallery and. The shear zone therefore does not influence the reported seepage, in any way. It is thus concluded that the copper strip provided to seal the construction joints might have corroded, giving way to the dam water to seep through from u/s face of the dam along the construction joint. Due to the hydrostatic head, seepage water in the chocked drain (16FF1), has found the passage through the block joint 15/16 which is in its near proximity.

The seepage and the dam water level were analyzed and the results indicated, that the seepage stopped while the water level goes down to the level of intermediate gallery, i.e., 128.50 m. Therefore it was concluded that, the reason for seepage in the intermediate gallery is due to damage in the construction joint, between block 15 & 16 and not due to any geological factor.

It is therefore recommended to ream the formed trap drain by suitable means and to grout the leakage during the lean period, after the water level drops down, below the level of intermediate gallery level, after a careful check of the copper seal.

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