GEOLOGY AND FOUNDATION TREATMENT OF KULEKHANI DAM, CENTRAL NEPAL

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सारांश

कुलेखानी जल विद्युत आयोजना स्थल काठमाडौं कम्प्लेसको भिमफेदी समूहको चट्टानमाथि अवस्थित छ। त्यस क्षेत्रमा पाईने प्रमुख चट्टानहरूमा कालीटार संरचना, चिसापानी क्वार्जाइट र कुलेखानी संरचनाहरू हुन्। उक्त क्षेत्रको मध्य भागमा पालुङ्ग ग्रानाइटको पोण्डको पनि अविच्छेदन भएको छ। दक्षिण भागमा ऐलुमियम डिपोजिटको विस्तृत विकास भएको छ।

यस बांधको जग कुलेखानी संरचनाको क्यार्जाइट र शिष्ट माथि अवस्थित छ। यी आधार चट्टानहरू नदीका दुवै किनारमा अन्य ठाउंमा भन्दा केही कमजोर छन्। तसर्थं जगमुनिबाट पानी छिर्न न सकोस् भन्ने हेतुले बाधको जगमा खदिला चट्टानहरू न भेडुन्ज्याल सम्मको गहराई भएको कोरट्रेन्च खनि त्यसपछि १०० मिटरको गहराइसम्म आवश्यक उपचारिक कार्यहरू गरिए।

ABSTRACT

The Kulekhani Hydroelectric Project is located in Bhimphedi group of Kathmandu complex. Kalitar formation, Chisapani quartzites and Kulekhani formations are the main rock types with Palung granite massif intruded in the middle part of the area. Alluvial deposits are widely developed in the Southern part.

The dam foundation consists of quartzites and schists of Kulekhani formation. The foundation rocks are weaker on both the banks. Core trench was excavated up to the level of sound rocks and foundation treatment done up to 100m depth rendering the foundation watertight.

INTRODUCTION

The Kulekhani Hydroelectric Power Project is located on the Kulekhani river in Makwanpur district, Central Nepal (Fig. 1). It consists of a rockfill dam 114m high and 406m long, a headrace tunnel 6223m and an underground powerhouse housing two generating units with a total capacity of 60 MW. A reservoir, 8 km long having 85 million cubic meter capacity, is created by the dam. Out of 85 million m^3 only 73 milion m^3 of water is used for power generation, the remaining 12 million m^3 is left as dead storage for sediments to accumulate. The dead storage is expected to be filled in 75-100 years.

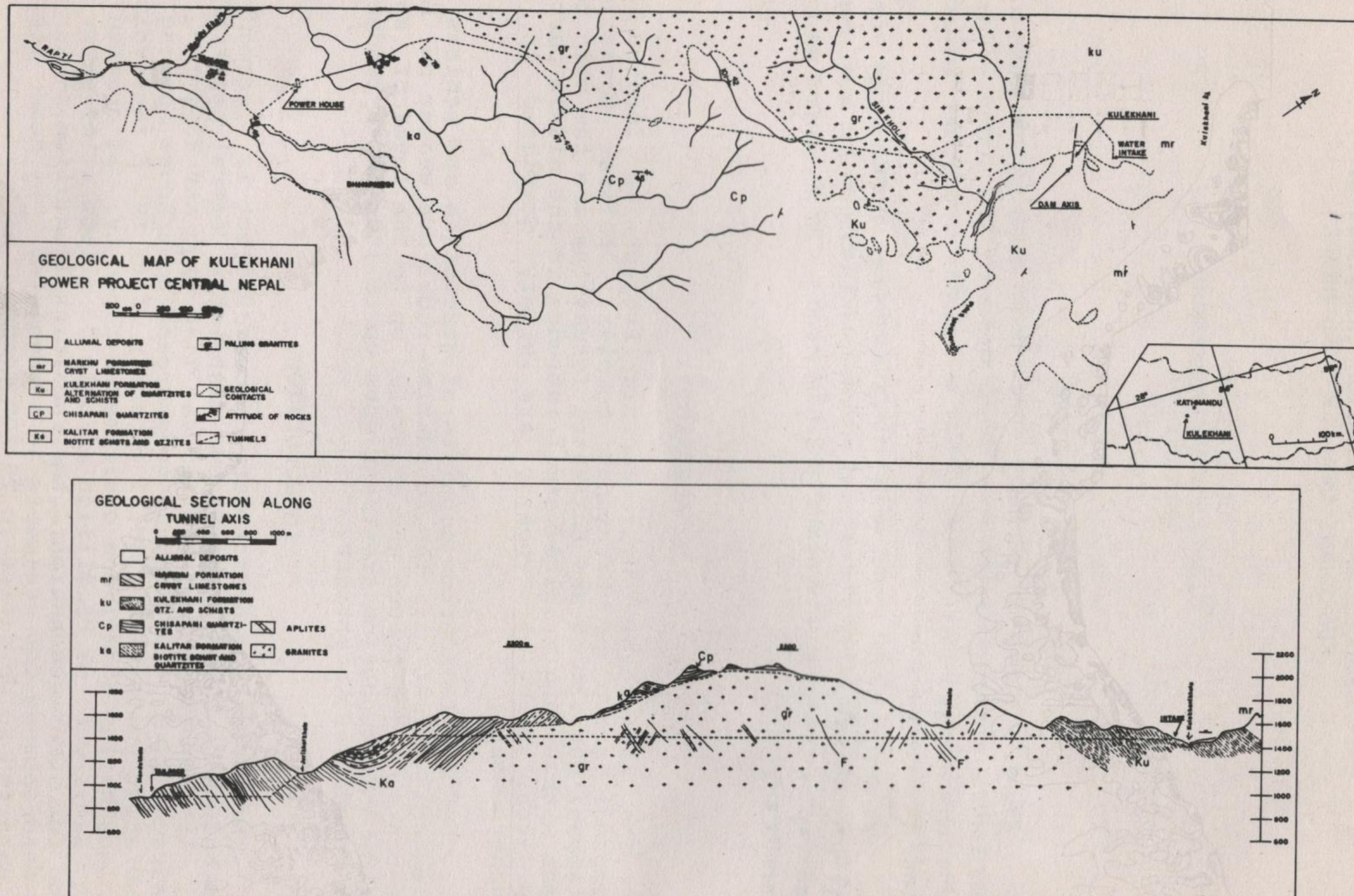
GEOLOGICAL MAP OF KULEKHANI
POWER PROJECT CENTRAL NEPAL
ALLUVIAL DEPOSITS
MARKHU FORMATION CRYST LIMESTONES
KULEKHANI FORMATION ALTERNATION OF QUARTZITES AND SCHISTS
CHISAPANI QUARTZITES
KALITAR FORMATION BIOTITE SCHISTS AND QTZITES
PALUNG GRANITES
GEOLOGICAL CONTACTS
ATTITUDE OF ROCKS
TUNNELS
POWER HOUSE
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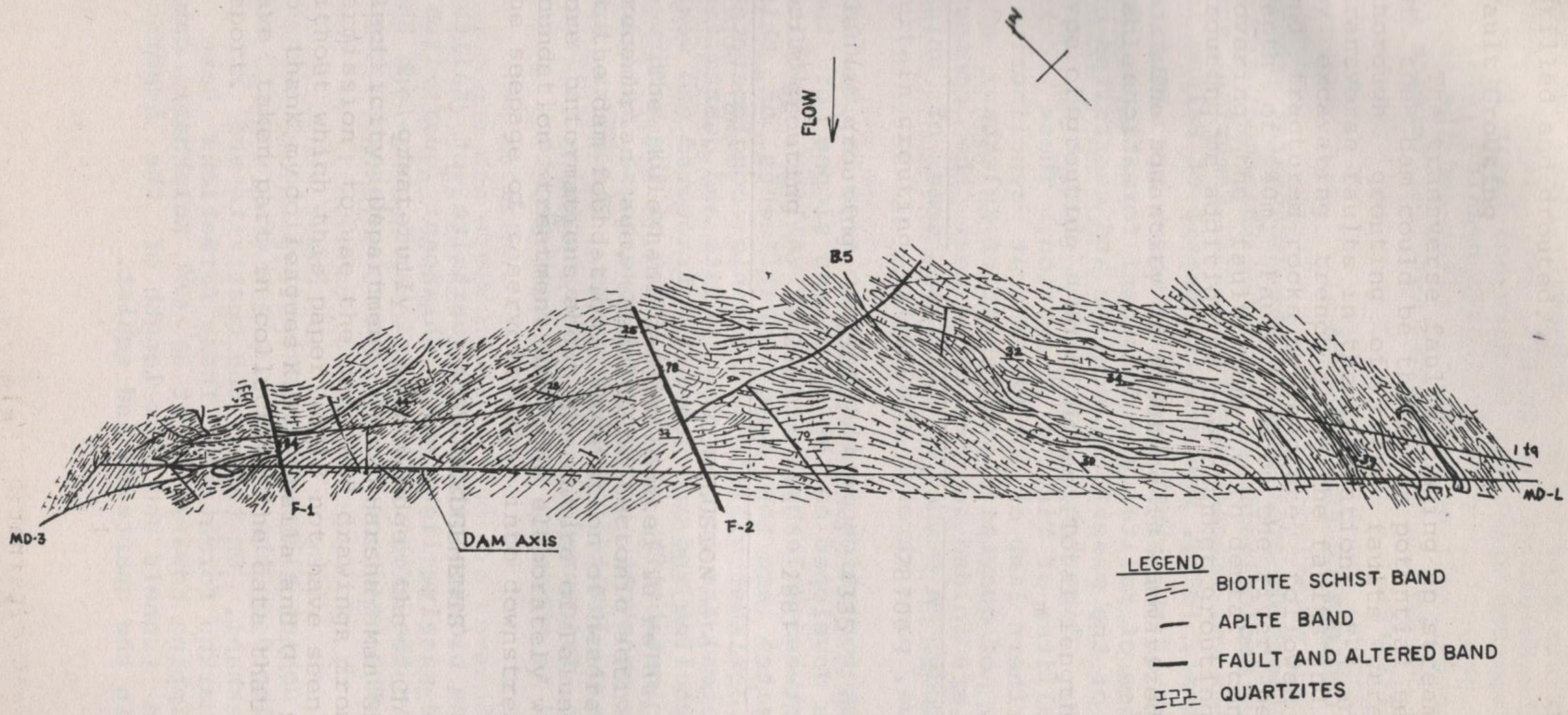
Fig. I



GEOLOGICAL MAP
OF
KULEKHANI DAM FOUNDATION

Fig. 2

0 10 20 30 40 50m

Kulekhani river is a tributary of Bagmati river and its catchment area at the Kulekhani dam is 126 km^2. Inter basin transfer of water from Bagmati basin to Narayani basin is made in this scheme. The project is conceived as a peaking station utilizing the monsoon runoff of Kulekhani river and the high head obtained (614m) due to the topographic level difference of Kulekhani and Rapti rivers.

GEOLOGY OF PROJECT AREA

The Kulekhani-Bhimphedi area lies in the Mahabharat range south of Kathmandu. Geologically it is in the Bhimphedi group of Kathmandu complex of Precambrian to Lower Cambrian age (stocklin and Bhattarai, 1977). The granite massif of Palung is located in the middle of the area, south of which are biotite schists and quartzites of Kalitar and Chisapani formations. On the northern flank of the massif are schists and quartzites of Kulekhani formation, limestones of Markhu formation and quartzites and phyllites of Tistung formation. These rocks constitute the sourthern limb of the Mahabharat synclinorium. The metasedimentary of quartzite and schist of Kulekhani and Kalitar formation are folded and fractured near the contact with the granite body. A number of faults, some of which believed to be active, pass through the area.

The oldest rock formation in the project area is Kalitar formation which is developed on the sourthern slopes of the Mahabharat ridge between Kulekhani and Rapti valleys. Biotite schists and quartzites are the main constituents of this formation. Around Jurikhet village metamorphic conglomerates (Jurikhet conglomerates) are found. The schists and quartzites are folded into a syncline and are generally fractured and weak contributing to the instability of slopes. Part of the headrace tunnel, surge tank, penstock, underground powerhouse, tailrace and access tunnels are located in these rocks. The rocks are less weathered and fractured in the powerhouse - tailrace tunnel area compared to those on the surge tank-penstock parts of the project.

On top of the biotite schist and quartzite of Kalitar formation are found massive light grey Chisapani quartzites. They are developed in the area of Chisapani Garhi and along the Mahabharat ridge. The headrace tunnel passes underneath these quartzite (Fig. 1).

Quartzite and Schist alternation belonging to Kulekhani formation are developed on the northern slope of the ridge and in the area of Kulekhani. On top of the quartzite and schist are limestones of Markhu formation. These formations have a strike of SE-NW dipping towards NE at 30°-40° Kulekhani dam, spillway, diversion tunnels and 900m length of the headrace tunnel are located in the quartzite and schist.

The Palung granite massif is located in the central part of the project area forming the highest peaks in the Mahabharat ridge. The granites are of the biotite granite and tourmaline granite types. As an intrusive body they cut into the Kulekhani, Chisapani and Kalitar formations. Outcrops of granite are found in depressions in the metamorphic formations too. The headrace tunnel passes through granites for about 4800m where the contact of the Kalitar and Kulekhani formations with granite is clearly observed. On both the flanks the granites have 'lifted' the metasediments. The contact with Kulekhani formation is dipping northerly while with the Kalitar on the south is dipping toward south forming a dome. In the middle parts Chisapani quartzite is observed on the surface whereas in the tunnel underneath are granites only. The quartzite of Chisapani is in the form of roof pendant (Fig. 1). Xenoliths of Chisapani quartzite and schist of Kulekhani formation are frequently found in the tunnel. Pegmatite and aplite dykes are widely developed. A number of faults are also observed. The granites were used as shell material for the fill dam.

Recent alluvium and old terraces are developed along Kulekhani Khola and in the area of Bhimphedi. Colluvial deposits are formed on the slopes in Kulekhani formation in the vicinity of dam and upstream.

GEOLOGY OF DAM FOUNDATION

The valley of Kulekhani rivers at the dam is of assymetrical shape with the left bank slope steeper than the right bank. The river channel is 50m wide. The bed rock is quartzite and schist alternation of Kulekhani formation. On the left bank the rock is mainly quartzite, hard ad massive. It forms steep cliffs with slopes 1:0.3 to 1:0.6 (V:H). On the right bank the slopes are considerably gentle (1:1.2 to 1:1.7) and consist of intercalation of quartzite and schist which are highly weathered and fractured. An old landslide is located on the right bank just dowstream of the dam; the slopes are full of talus material. On the river bed too the rocks are fractured. The rocks are striking NW-SE and dip towards up stream at 30-40 (Fig. 2). A series of transverse faults is located along the river bed and on the right bank. The transverse faults F-1 and F-2 are a zone of crushed rock filled with clay, 2 and 0.5 m wide respectively. Fault F-5 runs along the river bed. It is a zone of fractured rocks. Within this zone the quartzite and schist bands stand vertically as well. Strike faults which are outside of the geological map were found in the headrace tunnel in the form of a 30m wide zone of highly fractured rocks.

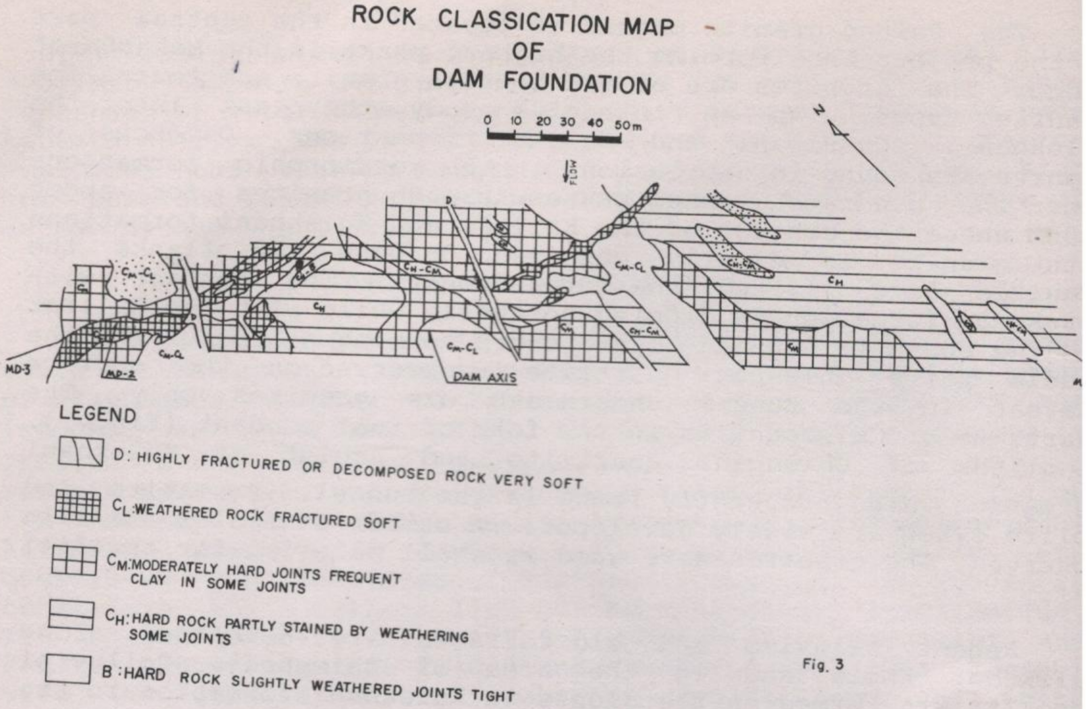


Fig. 3

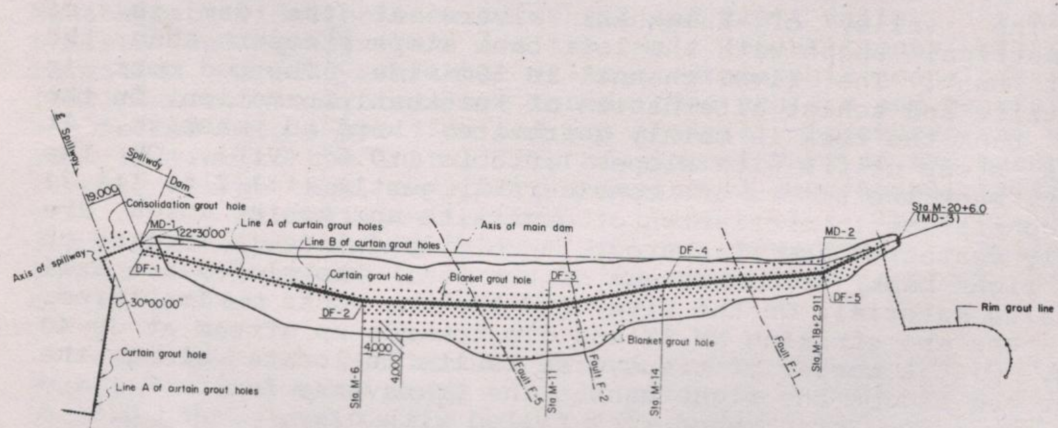


Fig. 4 Arrangement Plan of Grouting Holes in Damsite

0 20 40m.

Form the rock classification map of dam foundation, (Fig. 3) it is seen that rocks on the left bank are of better quality than on the river bed and right bank. CH class which represent the hard rock with very little weathering (Standards recommended by JNCD for Geological investigation of dam foundation) are distributed mainly on the left bank and in portions of right abutment and river bed. The weakest rock condition class-D are found along the faults F-1 and F-2. Moderately hard and weathered rocks (class CM and CL) constitute the river bed portion and right bank of the dam foundation.

FOUNDATION EXCAVATION

Detailed engineering study of the dam foundation, by boring, seismic refraction and test aditing showed that the rocks on the right abutment were highly weathered to a depth of 30m, while on the left bank the rocks were sound. On the river bed the alluvium was 10m thick. A foundation trench was proposed for the core zone in which excavation was done to the level of sound rocks. Thus, a deep trench was formed on the right bank and at the river bed and the alluvial deposits of the terrace on left bank were removed to reveal the bedrocks. Up on the left bank will slope sound bed rocks formed a cliff. It required little excavation. However, the slopes steeper than 60° were made gentle. The excavation were done by dozers with ripper, explosives were used on the left bank and on steep faces on the right bank. A total of 686000 m^3 material was excavated for the dam foundation. The cut slopes on left and right abutments were 1:0.7 and 1:1.2 respectively.

FOUNDATION TREATMENT

The foundation conditions under the core and filter zones of the dam were improved both at the surface and in depth. The surface treatment consisted of cutting and reshaping of irregular surface and filling with mass concerte of pot holes and fractured areas. Dental concerting to cover the uneven surfaces was done in the riverbed portion. On the steeper slopes on either banks reshaping concerte was used to obtain the required slope of 1:0.7.

The subsurface treatment of foundation was carried out according to an elaborate grouting plan (Fig. 4) which covered the entire foundation under core zone and extended to the spillway on the left bank and about 100m upstream on the right bank. The main purpose of grouting was to fill up cracks in the bedrocks in order to minimize the seepage of water from the reservoir through the foundation rocks into the downstream part of the river. Three types of grouting were carried out:

- Curtain grouting
- Blanket grouting
- Fault groutng

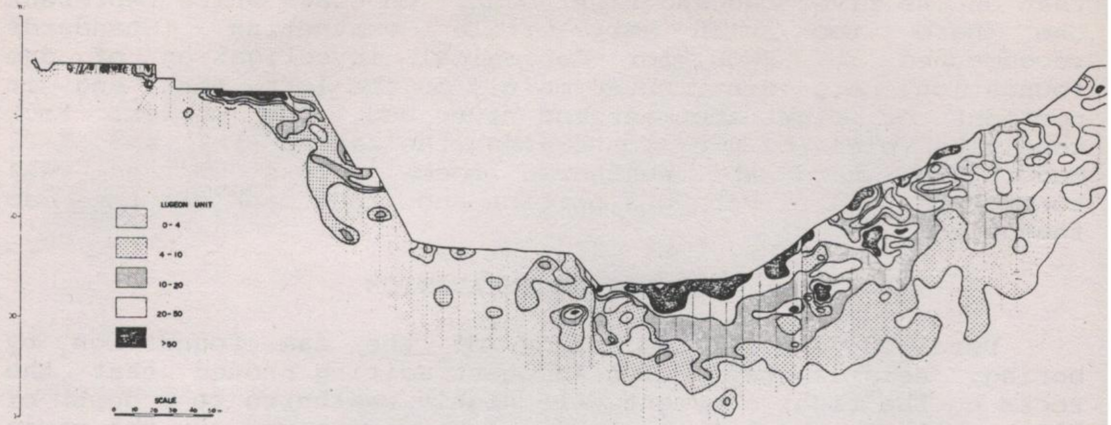


Fig 5a Permeability Profile of Main Dam Curtain Grouting, Primary Holes

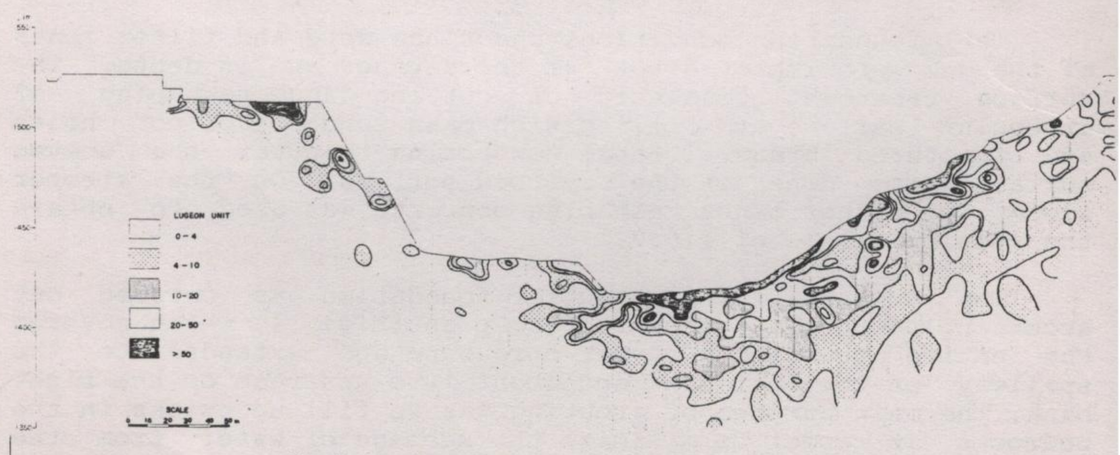


Fig. 5b Permeability Profile of Main Dam Curtain Grouting, Secondary Holes

Curtain Grouting

The plan consists of two parallel rows of drill holes extending from one abutment to other along the middle of the core foundation. The two rowsare 1m apart.The row in the upstream side is A line and the downstream one B line. The depth of curtain grout holes varied from 20 m on the left bank to 100m on the right bank. Grouting was done by the down stage zonned split spacing method. After grouting all the holes to one stage second stage is started. Grouting is done from top to bottom. According to the sequence the grout holes were grouped into primary, secondary, tertiary and quarternary holes. The primary holes are located 8m apart on A line and secondary in between them and tertiary in between primary and secondary. The quarternary holes are located on B line. Length of each stage was 5m upto a depth of 40m, 7m up to 80m and 10m in the last two stages upto 100m. Similarly grouting pressure varied from 2 Kg/cm^2 at first stage to 25 Kg/cm^2 below the depth of 67 m. To prevent grout leakage from the rocks under high pressure a cap concrete 2m wide was placed along the grout line from where grouting was done. Grout material was portland cement-water mixture of various porportions, generally 1:10. The cement water ratio was subject to change depending upon the permeability of the rocks and rate of injection. In highly fractured area cement sand mortar and bentonites were also used.

The permeability of the rocks was determined by carrying out water pressure test in each grouting stage under the same pressure as for grouting. The water pressure test is a basis to determine the cement water ratio of the grout. Upon completion of curtain grouting check holes were drilled at slected points to see the effect of grouting. In case when the final permeability of the rocks was more than 4 Lugeon units additional grouting were done. Figures 5 and 6 show the permeability profiles of primary, secondary, tertiary and quarternary holes. It is seen that a gradual decrease in permeability after each grouting was well achieved.

Blanket Grouting

Blanket grouting was done in order to consolidate the rocks and control seepage at shallow depths. The blanket grout holes were spread over the core zone foundation up stream and downstream of the curtain grout lines. Upto 8 rows of holes were located on the riverbed portion in the upstream side of the curtain grout line. Two rows were placed in the downstream section. The blanket grouting was done mainly on the riverbed and right bank portions of the foundation. One row on either side of the curtain grout line on the left bank was also made. Depth of holes vaired from 5m on the left bank to 25m on the right bank. Grouting procedure was similar to curtain groutng except that the sequence of primary, secondary holes was not observed. Every alternate hole was drilled and grouted and after allowing for cement to set, the holes in between were

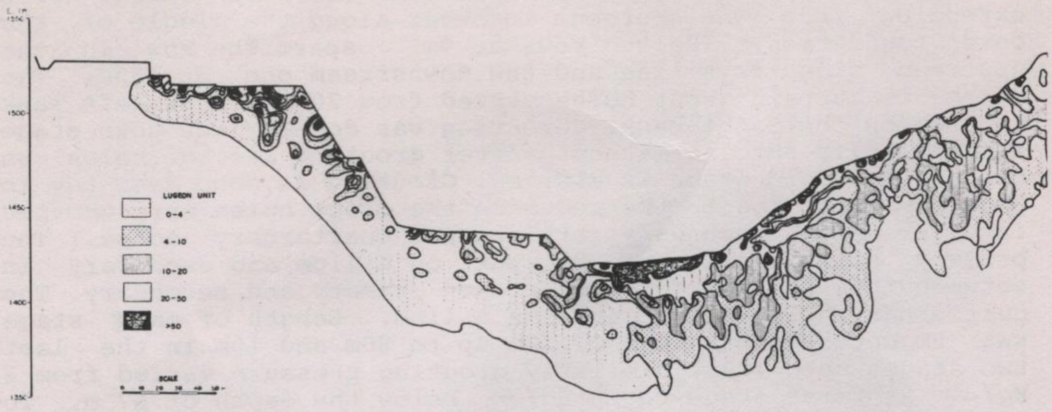


Fig. 6a Permeability Profile of Main Dam Curtain Grouting, Tertiary Holes

Fig. 6b Permeability Profile of Main Dam, Quarternary Holes (B Line) and Additional Holes (B Line + A Line)

drilled and grouted.

Fault Grouting

The transverse faults running up stream to downstream part of the dam could be the major potential seepage paths. So, a thorough grouting of these faults were required. Major transverse faults in the foundation: F-1 and F-2 were treated by excavating trench along the faults and replacing the clay and fractured rocks by concrete, followed by grouting upto a depth of 40m. Fault F-5 on the river bed was treated by covering the fault zone with dental concrete and shallow grouting in addition to the blanket grouting already performed.

The quantity of grouting is summarized in the following table:

Type of grouting	No.of holes	Total length m	Cement quantity tonnes	Cement consumption per m Kg/m^2
Curtain grouting	686	28700	2200	77
Blanket grouting	550	4335	500	115
Fault grouting	266	2881	200	71

CONCLUSION

The Kulekhani dam is located in relatively weak rocks of Precambrian age. Results of tectonic activities are witnessed at the dam foundation. Excavation of headrace tunnel has added more informations about the nature of Palung granite massif. Foundation treatment was done elaborately which has controlled the seepage of reservoir water into downstream to a minimum.

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