PERMEABILITY OF RANDENIGALA DAM FOUNDATION

by

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SYNOPSIS

The geotechnical investigations conducted during the feasibility study and the detail design stage prior to preparation of tender drawings in the Randenigala Project area, covered the foundation areas of all structures, and facilitated an overall assessment of the rockmass permeability. However those general conclusions were inadequate to make an accurate evaluation of the permeability of the dam foundation (core trench) which was required for the design of grouting works. Hence, during the very initial stage of construction of this project a special investigation programme was carried out along the dam axis, to obtain the quantitative characteristics of permeability of the core trench area.

Below given are the conclusions (only relevant to the subject dealt by this paper) of the geotechnical investigations conducted up to the stage of preparation of tender drawings. Then elaborates in detail on the special investigation programme, conducted along the dam axis in the core trench area including the methodology.

Consequently, the test results are analysed with an accurate assessment of the permeability characteristics of the core trench. Finally, the conclusions relevant to the construction of the grouting gallery and the extent of consolidation & curtain grouting required are made.

1.0 INTRODUCTION:

Evaluation of the rock mass permeability of Randenigala Project Area was done as one of the main objectives of it's geotechnical investigation programme during feasibility study and detail design phase. It covered the foundation areas of all structures i.e., dam, spill way, diversion tunnels, power intake, high pressure tunnel, penstocks and power house. Under the said programme thirty one number of Nx size, bore holes with varying depths from 40m to 200m, of inclinations varying from 0° (vertical) to 50° were carried out, totaling to a metreage of 2493m In all these, Lugeon type permeability tests were conducted, core recovery and rock quality designation were too recorded. Two exploratory adits on either banks in the core trench were too exectured.

The above were too recorded geotechnical investigation programme facilitated a reasonable assessment of the rock mass permeability of the total project areas as it covered both Mahaweli river banks more or less uniformly. Also as a result of it main engineering geological factors which determine/affect, the permeability of bed rock were established. Results of the said permeability tests indicated a very high variation in three dimensions and was dependant on occurrence of foliation joints, fractures/fracture zones, of tectonic origin and the degree of weathering of rock, in an irregular manner.

Besides the said facts, only four numbers of bore holes fell within the dam foundation i.e. core trench, where foundation treatment as consolidation and curtain grouting was anticipated to be performed from a grouting gallery.

Above referred to results of permeability tests indicated a very highly permeable zone (20,0-49.9 Lugeons) to a depth of about 20m and the next 20m zone was with highly (10,0-19.9 Lugeons) to very highly permeable (20.0 - 49.9 Lugeon) i.e. with a varying permeability in three dimensions. Below the said ±40m zone, highly, very highly and extremely highly (>50 Lugeons) permeable locations/zones of limited extension occurred and they were caused by deep fracture zones of tectonic origin.

According to the detail design the core trench was to be excavated to a depth of about 16-18m from the ground surface and the grouting gallery was to be located at an average depth of 15m from the bottom of the core trench.

The 75m long two adits indicated a steady water seepage, along the full length, at depths around 35m from the ground surface, during the rainy season. At that time the ground water level was measured in the prezometers showed a maximum at ±10-15m depths from the ground surface. Both adits were within the core trench area.

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The latter indications gave sufficient grounds to conclude that the general conclusions reached (during feasibility study & detail design stages) on the rock mass permeability of the project area were inadequate to make a judgement on the extent of the dam foundation treatment (grouting) required and at which depth the grouting gallery shall be located. Also they were deemed inadequate for the final design of the grout curtain.

Hence, during the very initial stage of construction a special exploratory programme was undertaken to obtain the required quantitative permeability characteristics pertinent to the core trench (Dam foundation) required for the design of the grout curtain.

2.0 ENGINEERING GEOLOGICAL CONDITIONS OF THE CORE TRENCH

The core trench area i.e. the dam foundation is formed by intermediate charnockite with pyroxene quartz and feldspar as main mineralogical components.

Three joint systems are very well developed in this area and their characteristics are given below:

a) Foliation joints (Strike W 353° N to N5° E, Dip 80° E - 90° - 82° W)
b) East West joints (Strike N84 ° E to E 96 ° S Dip 80° S - 90° - 79° N)
c) North South joints (Strike W 345° N to N13° E, Dip 64° W - 90° - 70° E)

East West striking joint set and North South striking joint set are of tectonic origin and reach great depths. The foliation joints predominantly occur in highly weathered rock and they are open. In moderately weathered rock and below generally open foliation joints are, scarce. As observed in slightly weathered and fresh rock weathering is observed only in fracture zones and in joints adjacent to them.

3.0 GEOTECHNICAL INVESTIGATIONS PROGRAMME OF THE CORE TRENCH

3.1 MAIN OBJECTIVES

- To evaluate the rock permeability of the core trench area.
- To determine the technically feasible depth, (from the bottom of the core trench) for the construction of the grouting gallery, from where the foundation treatment i.e. grouting was to be executed.
- To determine the extent of consolidation and curtain grouting required.

3.2 METHODOLOGY OF INVESTIGATION

To achieve the above objectives mentioned in section 3.1 eighteen numbers of exploratory drill holes with a total metreage of 1414 m were drilled along the dam axis to varying depths from 60m to 110.0m. The first eight (EHDA 1 to EHDA 8) of them were inclined 15° from the vertical towards north-west (towards left bank) the other ten bore holes (EHDA9 to EHDA 18) were inclined 20° from the vertical towards north-east (towards right bank). Locations of the bore holes along the dam axis are shown in figure No: 1. The positions of the said bore holes in section are also shown on the geotechnical section in figure No: 2.

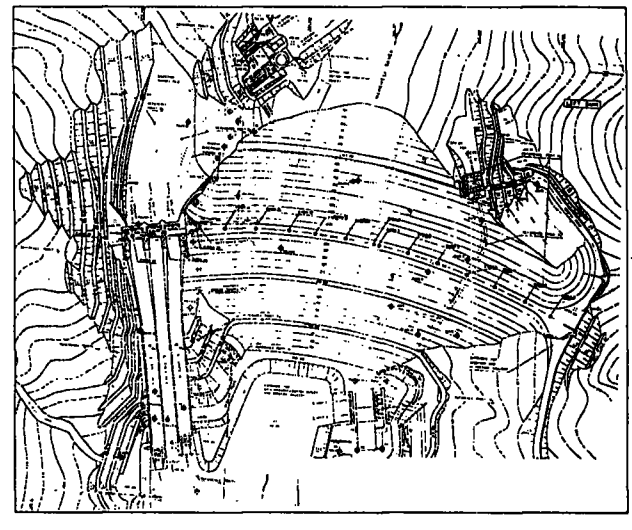


Figure 1 - General Layout of Randenigala Project and the Lacations of Exploratory Holes on the Dam AXIS

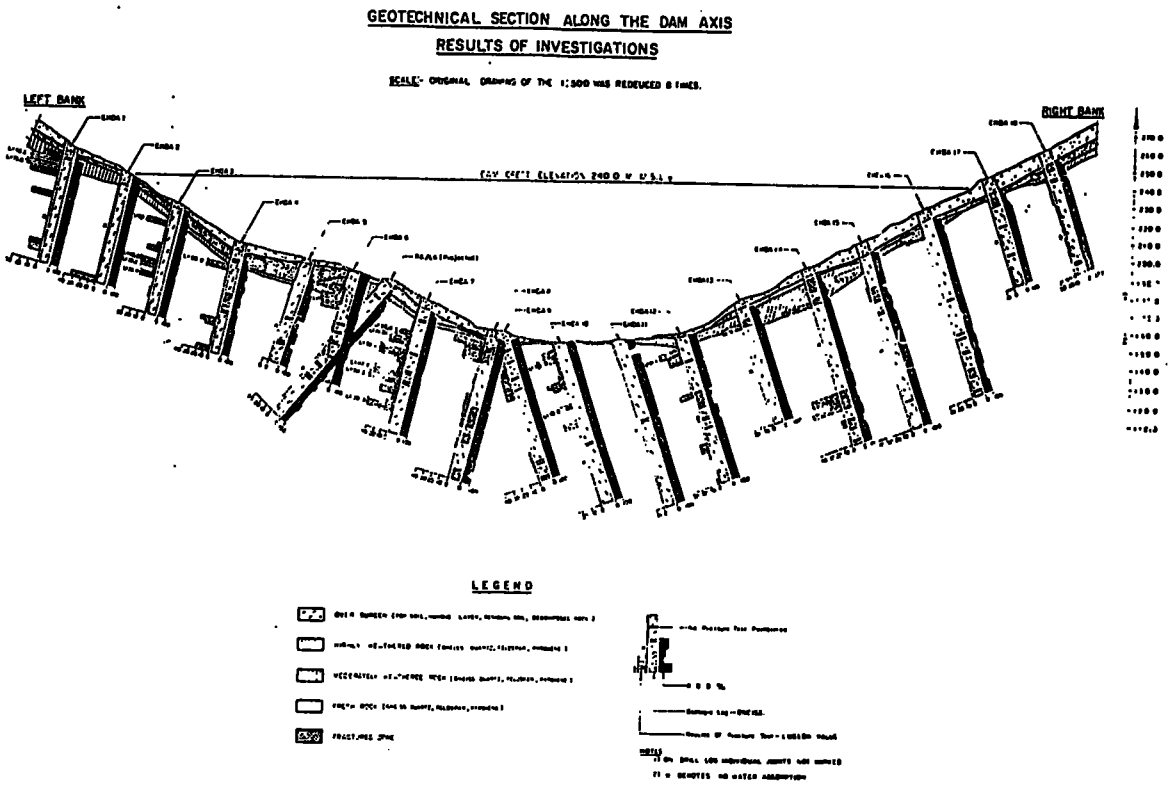


Figure 2 - Geotecnical Section Along the Dam AXIS (Results of Investigations)

The bore holes were drilled inclined as mentioned above in order to intersect a maximum number of joints of the three main joint systems occurring in the foundation area (a brief description of the engineering geological conditions of the core trench is given in section 2.0).

The distance between the bore holes were selected in such a manner so that the complete section along the dam axis under the dam is covered without gaps. (Evert 1986) to a depth of about 80-100M, in order to not to miss any of the EW trending main fracture zones of the tectonic origin

In all the exploratory holes water pressure tests according to the Lugeon method were conducted to determine the permeability. The lengths of the test stages were approximately 3m. One complete Lugeon test comprised five pressure stages (2-5-10-5-2 bars) in ascending and descending succession. Each pressure step was maintained six (ten minutes if the absorption was low) minutes. The obtained water loss (absorption) was expressed in Lugeons, (Houlsby 1979).

On drill cores recovered the rock quality designation (RQD) and core recovery (as a percentage) were recorded.

4. ANALYSIS OF TEST RESULTS

In analyzing the data related to permeability of rock the following classification of rock according to permeability based on Lugeon value criterion was adopted, (Ewert 1985)

< 1 Lugeon	-	Technically impervious
1.0 -4.9 Lugeon	-	Moderately permeable
5.0 - 9.9 Lugeon	-	Distinctly permeable
10.0-19.9 Lugeon	-	Highly permeable
200-49.9 Lugeon	-	Very highly permeable
>50.0 Lugeon	-	Extremely permeable

(Houlsby 1979)

Results of geotechnical investigations done along the dam axis are shown in figure No:2-Geotechnical section along the dam axis. Results of the water pressure tests are given in figure No: 3, which indicates the variation of water absorption (in Lugeons) with the depth.

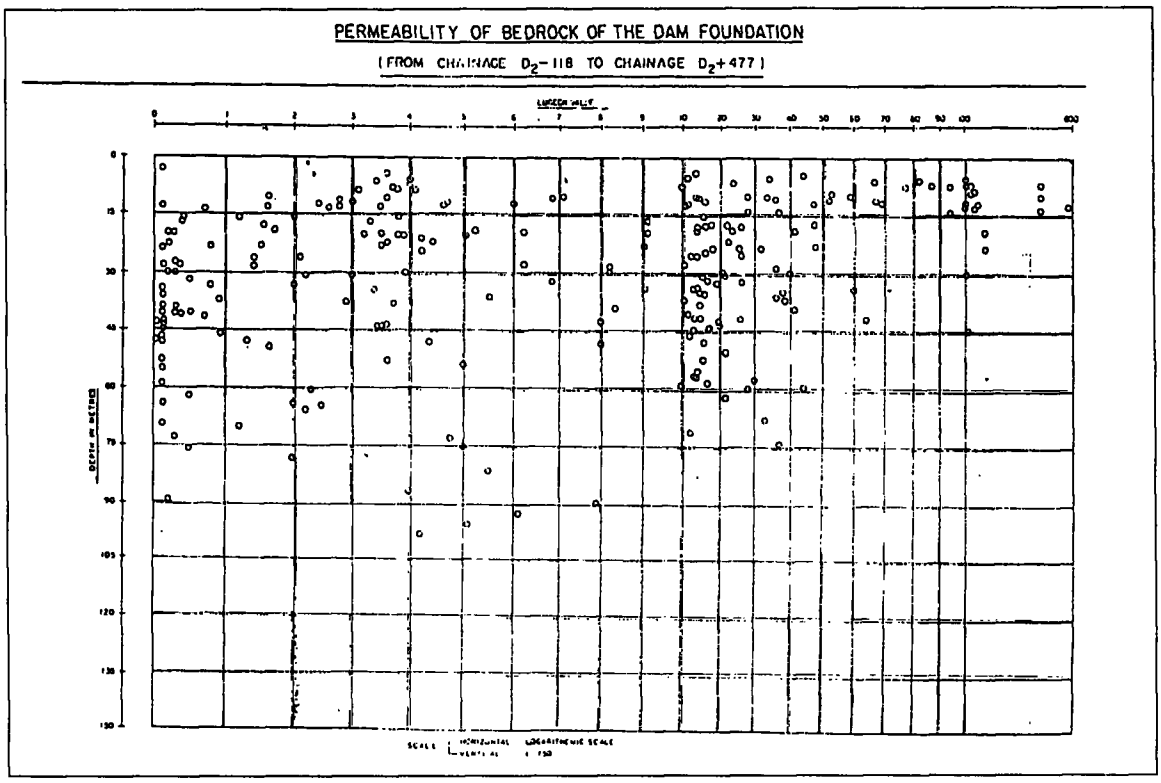


Figure 3

As per the results of the water pressure tests 245 numbers shown in figure No:3 the bed rock of the core trench can be zoned with depth as shown below.

a) Extremely permeable zone with >50.0 Lugeons from 0.0m to 30.0m deep

b) Highly permeable zone with predominantly <20.0 Lugeons with about 12 values >20 Lugeons form 30.0 m to 60.0m depth.

c) Moderately to distinctly permeable zone with <10.0 Lugeons (just four results 10.0-50.0 Lugeons) from 60.0m to 90.0 deep.

As the bottom of the core trench was to be at a depth of 16-18m from the ground surface, in moderately weathered or fresh rock, top part of extremely permeable rock zone any way was to be excavated as per the detail design.

In the highly permeable zone from 30.0 to 60.0m where water absorption predominantly is less than 20.0 Lugeons in, moderately weathered and fresh rock the permeability is determined mainly by the degree of fractured-ness. The individual Lugeon values 20.0 to 100.0 Lugeons can be attributed to fracture zones of tectonic origin.

On the basis of the above data the construction of the grouting gallery from where grouting works were anticipated to be executed was deemed to be technically prudent to be lowered to a depth of about 45.0m from the ground surface to avoid problems associated with inflow of ground water, specially at lower elevations and under the river bed.

(According to the detail design the grouting gallery was about 15m below the core trench i.e. about 30-33m from the ground surface, where the grouting gallery would have been in the upper part of the extremely highly permeable zone.)

Also the said new permeability values relevant to the rock zone between the grouting gallery and the bottom of the core trench clearly indicated the necessity for an intensive grouting programme i.e. multiple row consolidation grouting covering the full width of the core trench.

The permeability of the rock below the grouting gallery was considered to be adequate for the rock to be treated with a single row "grout curtain", to a depth of about 90m from ground surface.

5.0 CONCLUSIONS

The results of the geotechnicl investigations (exploratory adits drilling and permeability test results) of feasibility study and detail design phase indicated the following permeable zones in the rock mass of the project area: Very highly permeable zone (up to 50 Lugeons) to a depth of 40m from ground surface. Next 40m zone only had a few highly to extremely perme-

able zones of limited extension and they were attributed to tectonically formed fracture zones.

- The above generally facilitated the conclusion to construct the grouting gallery at a depth of about 30-33M from the ground surface and to treat the rock above the gallery with consolidation grouting. In the rock below the grouting gallery a grout curtain was to be constructed.

- As the above permeability test results were considered inadequate to design the grout curtain along the dam axis and to determine the quantum of grouting work required, a special exploratory programme was conducted along the dam axis (in the core trench area) to determine the permeability characteristics of this location.

- The results of the above exploratory programme indicated the following zonation of rock according to the permeability characteristics.

  a) Extremely permeable zone (>50.0 Lugeons) from 0.00 to 30.00m depth from ground surface.

  b) Highly permeable zone (predominantly <20 Lugeons with a few exemptions i.e. 10% up to 50 Lugeon) from 30.00m to 60.00m depth.

  c) Moderately to distinctly permeable zone (with <10 Lugeons) from 60.00m to 90.00m depth.

- Hence the grouting gallery was lowered to a depth of 45m (midpart of the highly permeable zone) where permeability of rock is relatively low as shown in figure No:3, to avoid construction problems due to inflow of ground water particularly in lower part of the river valley and in the river section. Further, the grouting gallery was recommended to be excavated during the dry season (March to September), particularly the rock excavation was scheduled to be in latter part of the dry season when the river flow was at its lowest and the river was completely diverted through the diversion tunnels (on the right bank) with no water flowing over the dam foundation area.

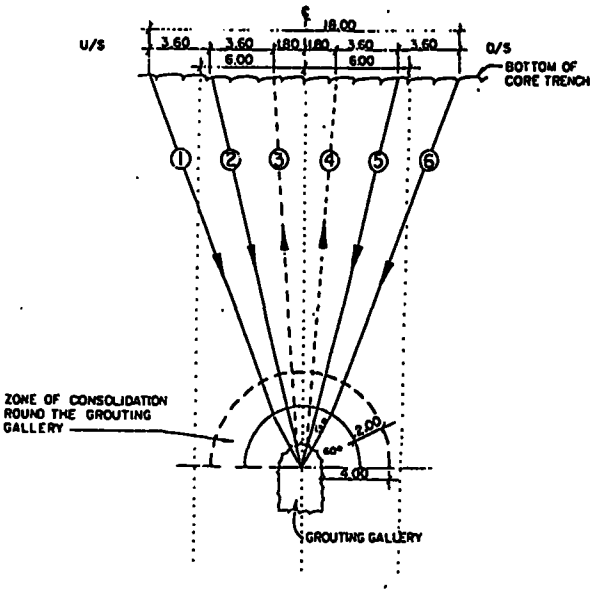
- After construction of the grouting gallery a four metre zone around the gallery was to be treated with consolidation grouting to further control water inflow during the following construction period and particularly when the reservoir is impounded to the full supply level which will result in a hydrostatic pressure of about 15.5 bars at the elevation of the gallery.

- Rock mass between the grouting gallery and the bottom of the core trench was recommended to be treated with consolidation (multiple row) grouting covering the full width of the core trench bottom (see figure No:4). In the lower part of the foundation, below the gallery a single row grout curtain to a depth of 40m from the gallery, was recommended to be constructed, in 3 phases with hole spacing 6,3 or 1.5m as required.

- All grouting works, except the outer holes of the grout fan above were to be performed from the grouting gallery in order to minimizing interference, with the other construction work of the dam.

- The design of the grout curtain was to be finalized after performing a test grouting programme performed in a representative area within the dam foundation limits.

TYPICAL CROSS SECTION OF THE UPPER SECTION OF DEEP GROUT CURTAIN



TYPICAL PLAN VIEW OF GROUT HOLES IN CORE TRENCH (BOTTOM)

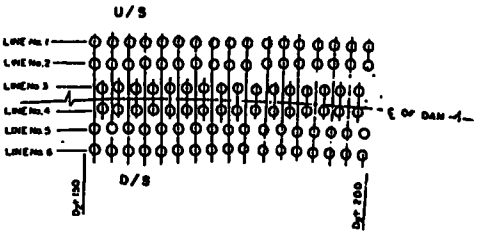


Figure 4

6.0 ACKNOWLEDGEMENT

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7.0 REFERENCES

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