

ENGINEERING GEOLOGY OF RANDENIGALA HYDRO POWER PROJECT SITE

by

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SYNOPSIS

Geotechnical investigations for a hydropower project are conducted in stages, in order to establish the engineering geological conditions, which invariably here a direct impact on the selection of locations of structures, methods of foundation treatment/stabilisation and construction of foundations/substructures etc. Hence, it is of utmost significance to perform a very comprehensive engineering geological study, for such projects, as it will also, in addition to the above mentioned facts affect the economic feasibility of the project.

This paper shows how geotechnical investigations were conducted for the Randenigala Hydro Power Project, including the different types of methods utilized along with their purpose.

The paper discusses the relevant regional geological aspects in a certain but limited detailness and consequently elaborates mainly on the engineering geological conditions prevailing at Randenigala Project Site, indicating their effects on the dam foundation (shell area and core trench) excavation, surface preparation prior to fill placement and slope stability.

1. INTRODUCTION

Randenigala Hydro Power Project Site is located in the valley of river Mahaweli between Victoria Dam and Minipe anicut (about 5.4 km upstream of Minipe anicut) about 35 km South East of Kandy. (see figures No: 1 and 2)

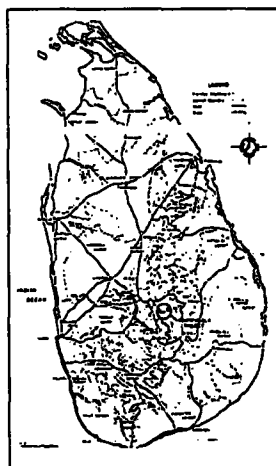


Figure 1 - Map of Sri Lanka

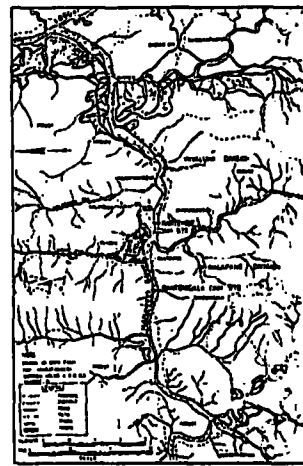


Figure 2 - Randenigala Project Area

The project consists of a hundred and two metre high rockfill dam with a clay core, chute spillway (maximum capacity 8085 m³/s), power house (installed capacity - 120 MW), power intake with steel lined power tunnel, irrigation outlet and other pertinent structures.

At the very inception geological mapping of the reservoir area (scale 1:25000) and the dam site (scale 1:1000) was carried out along with an aerial photographic study.

2. ENGINEERING GEOLOGICAL INVESTIGATIONS

The engineering geological investigations carried out in the Randenigala Project area comprise the following:

Exploratory drilling with core recovery (Nx, size diameter) was performed in two stages, i.e. preliminary / fea-

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sibility study stage and detail design stage. During the first stage nine (inclined and vertical) bore holes totaling to a metrage of 924M with depths varying from 60 to 200M were carried out while during the second stage, twenty two numbers of bore holes totaling to a metrage of 1570M with depths varying from 40 to 100M were sunk.

The exploratory drilling in bed rock was executed by using the triple tube core barrel for weathered formation and double tube core barrel for harder, moderately, slightly weathered and fresh formations, to obtain maximum core recovery, Further, in all bore holes Lugeon type permeability tests with ascenhdng and descending pressure steps 2-5-10-5-2 bars were performed.

On all the core samples, core recovery and R.Q.D. (rock quality designation) were recorded. The rock quality designation (RQD) is a criterion of the quality and soundness of the rock mass.

During the detail investigations also two exploratory adits were executed on either abutments at Randenigala dam site. Each of them was about 75.0M in length with a more or less square section of 1,8m width to obtain direct information about rock mass quality, excavation conditions in weathered rock and permeability/ground water conditions.

Further, about a 50m long exploratory trench was excavated to the bed rock on the left bank between elevations 195m MSL and 210 m MSL perpendicular to the dam axis in the East West direction.

In addition to the above, forty numbers of test pits were dug through the overburden to bed rock in the foundation areas of different structures to obtain direct information about the residual soil layer.

Locations of exploratory holes, test adits, pits, and exploratory trench are shown in figure No:5.

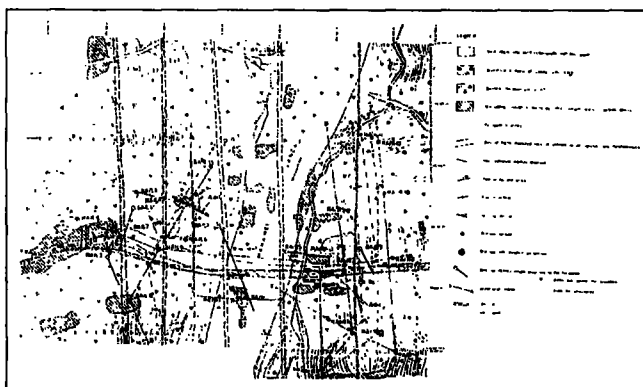


Figure 5 - Engineering Geological Map of Randenigala Site with Locations of Exploratory Holes & Adits

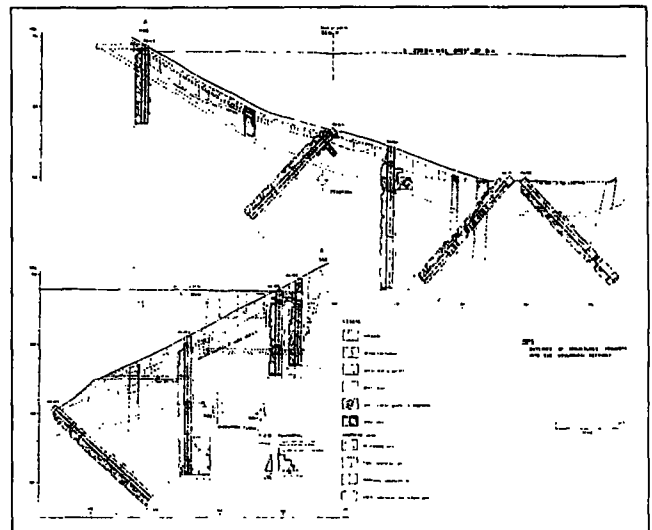


Figure 6 - Randenigala Dam Site Geo Technical Section A-A

3.0 MAIN GEOLOGICAL AND STRUCTURAL GEOLOGICAL FEATURES OF THE PROJECT AREA

3.1 LITHOLOGICAL FEATURES

3.1.1 Bed Rock of the Project Area

Randenigala project area is situated within the crystalline complex of Sri Lanka. This crystalline complex is the high grade meta-morphosed basement of the island. Above crystalline complex consists of three major divisions.

- Highland series: metasediments and charnockites in the central hill country.
- Vijayan series: gneisses, migmatites and granites north-west and south-east lowlands.
- South-western group: metasediments and migmatites in the south west lowlands.(Berger 1976)

The project area is entirely made up by the rocks of the Precambrian Highland Series which is represented by two major groups of rocks, (see figure No:3):

- Khondalite Group (Metamorphosed sediments)
- Charnockites

In the early years of geological studies it was considered that the series of metasediments and charnockites i.e. rocks of Highland Series is resting in a general syncline structure upon a basement of older gneisses, migmatites and granites of Vjayan Series. More recent studies propose that the Vijayan S'eries represents retrograde metamorphosed members of the Highland Series. The Vijayan series has resulted from an intense

period of metamorphism and orogenesis, the latter being accompanied by intense granitisation (Cooray 1984).

The rock of the Highland series are folded into a system named Tabrobanian fold system. The general direction of these folds is N-S to NW-SE. In the southern part of the central Highlands they run almost E-W whereas in the project and in the neighbouring areas the majority of the folds trend N-S and NNE-SSW. The axis of these folds are more or less parallel to each other forming a regular pattern of synclines and anticlines. Most of them plunge in the same direction, i.e. towards N to NNE.

The eastern boundary between the Highland Series and the Vijayan Series follows the river Mahaweli until Minipe and then veers to the east to embrace the Passara Hills. The character of the boundary being a fault line or a transitional zone is not yet profoundly investigated. (see figure No:3)

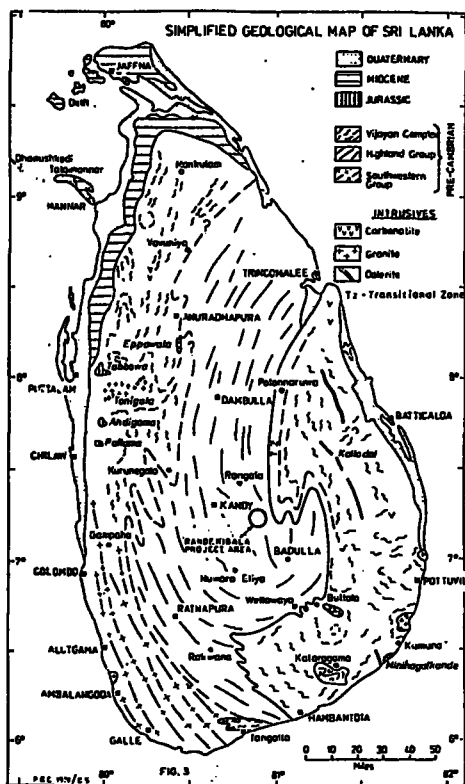


Figure 3 - Simplified Geological Map of Sri Lanka

However the studies of the aerial photos of the project area and Minipe revealed the existence of at least two major faults running NE-SW.

The ancient orogenic tectonism and more recent tectonic events probably related to destruction of the Gondwana shield and the subsequent uplift of the block of Ceylon (P.G. Cooray 1964) have resulted in the rock mass being divided by faults and fracture systems. Many of them run for 10 to 20 KM across the crystalline

rocks in an intersecting pattern which, in the project and in the neighbouring areas, shows a clear dominance in the E-W and N-S direction.

In the project area and in neighboring areas the Khondalite Group consists of the following rock types:

- Garnetiferous gneisses
- Quartzo - feldspar gneisses and granulites
- Marbles and calcsilicate gneisses
- Quartzites and quartzitic gneisses.

Charnockite group consists of many varieties of charnockites, with the typical and common property for all types of greenish-gray to bluish-gray colour, which is due to the fact that the dominant minerals in them quartz and feldspar are greenish or grayish in colour. The other common feature of all types of charnockites is the presence of (dark pyroxene) hyperstene. In this area observed are all three types of charnockites, basic, intermediate and acidic with varying percentages of quartz as the main and dominant mineral.

3.1.2 ALLUVIAL RIVER DEPOSIT

Alluvial river deposits i.e. medium to coarse grained sand and fine gravel occur in scattered, isolated deposits of small quantities in Randenigala project area.

3.1.3 TERRACE DEPOSITS

Several small, clayey, gravelly terrace deposits exist within Randenigala reservoir area occupying the relatively flat floors of some parts of the reservoir at elevations approximately 10 to 30m above river level. These gravels and clays are brown from oxidational weathering generally down to the bed rock.

3.1.4 TALUS, SCREE, SLOPE WASH, CREEP

The pre-cambrian crystalline rocks are almost every where in the project area covered by unconsolidated sediments which, however, vary in thickness and composition.

At the top of the ridges and hills accumulations of blocky material are often encountered, which are in place or slightly moved remainder, of outcropping bedrock.

Along the gently to medium steeply, inclined flanks of the hills, rock fragments of any size ranging from fine grained to big boulders were mantling the slopes. In the lower reaches of the hills blocky talus was accumulated to greater thickness.

The fine grained slope wash material was often accumulated in the comparatively flat, wide, down stream valley sections of major tributaries.

At the toes of cliffs and scarps, toppled or slightly creeping block masses occur.

3.2 STRUCTURAL GEOLOGIC FEATURES

The project area forms part of the structural unit of the Highland Series which is characterized by a regular pattern of approximately N-S trending folds.

Geological mapping and aerial photo studies indicate the existence of three major tectonic elements.

- a) Rantembe syncline
 - b) Fold and shear zone between Randenigala and Serasuntenna
 - c) Belihul Oya syncline
- a) In the eastern part of the project area, between Minipe and the Kehelella valley, slightly downstream of Randenigala, gneisses, quartzites and granulites form a syncline with an amplitude of 6-8km. The axis of the syncline runs approximately N-S crossing the Mahaweli near the confluence of Uma Oya. Towards the north, corresponding to the plunge of the axis, the syncline extends into the tributary of valley of Maha Oya.

These gneisses forming the core of the syncline are intensively folded, sheared and fractured. Tectonic intensity decreases towards the eastern and western limbs of the fold. The granulites at Randenigala on the western arm of the syncline generally are compact and massive.

- b) Eastern part of the Randenigala reservoir, between Kehelella valley and the area of Sarasuntenna, is characterized by folds and shear zones. The most prominent features are the anticline which is synform with the downstream reach of the Kehelella valley and the syncline, which is congruent with the wide Kurundu Oya Valley. Between these two structural elements a number of secondary (minor) anticlines occur and the secondary synclines are mostly substituted by shear zones.
- c) North of Serasuntenna, minor anticlines and synclines have been observed in the rock outcrops along the river. Together with shear zones they probably represent the contact to the adjoining syncline. The axis of this syncline, running approximately NNW-SSE, crosses Mahaweli near the confluence of the Belihul Oya.

The structural attitude of the syncline corresponds with that one of the Rantembe syncline with a more gently inclined eastern limb and a vertical to overturned western arms.

4.0 ENGINEERING GEOLOGIC CONDITIONS OF THE DAM AREA

4.1 GEOMORPHOLOGY OF RANDENIGALA DAM SITE.

At Randenigala dam site the river section is narrowest compared with the other parts of the valley (up stream or down stream) showing a width of the river bed of about 75 metres. (see figures No: 4 and 5.). The river has carved its bed into a hard and compact rock sequence of pyroxene gneisses, granulites, and quartzitic gneiss. Numerous outcrops appear within the river bed during the low water level season and recent alluvial sand and gravel make up only thin deposits of few metres thickness. It is apparent that a deep canyon (about eight metres) occurs along the river, filled with alluvial material. Along the right river bank, bedrock outcrops are exposed continuously, whereas they are scarce on the left bank. Towards higher elevations on both slopes blocky talus material covers the bed rock.

The right abutment rises smoothly up to elevation 240m MSL. with an inclination of about 25° and continues with about 30° up to elevation 400m MSL., forming a broad ridge, which finally summits at elevation 825m MSL. The blocky talus cover is locally interrupted by outcropping rock masses which may be partially detached from the stable rock, insitu.

The left slope rises with an inclination of 28° up to elevation 184 m grading there into a narrow terrace which is slightly inclined with about 13° towards the river. The terrace was made up by blocks, gravels and a sandy-clayey matrix.

From 200m, MSL upwards the slope shows an inclination of 29°.

A ravine cuts into this left abutment which drains a higher situated lateral valley of limited extension. The summit floor reaches heights of 825m to 850m, MSL.

Upstream of the dam site the valley widens considerably and N-S directed tributary streams drain large lateral valleys on both sides of river Mahaweli. (Figure No:4).

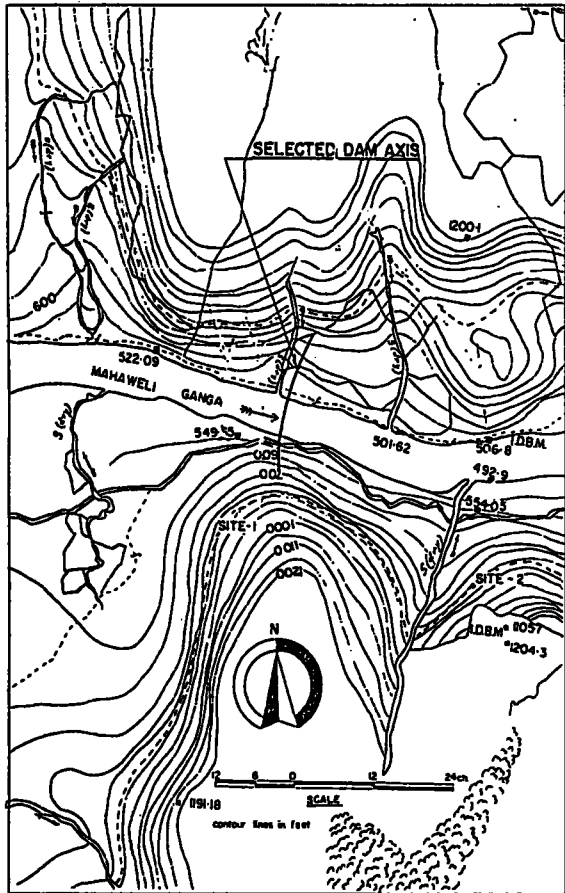


Figure 4 - Location of The Randenigala Dam (AXIS)

4.2 BED ROCK

Almost continuous rock outcrops along the river bed and scarce outcrops located within the rising hill flanks consist of a series of pyroxene amphibole gneiss, granulitic gneisses, quartz rich garnet gneisses and interbedded amphibolites, diopside felses and quartzitic rock types. Gneissic structure could be locally observed in rock out-crops but was less pronounced in the drill core samples. Generally an equigranular to granulitic fabric was predominant which resulted in a quite compact and thickly banded to massive appearance of the prevailing rock sequence. Schistous rock types did not appear within the dam site area.

An almost continuous profile of outcrops of massive rock strata could be observed along the lateral ravine on the left bank of the river at the dam site. (see figure No:5). the ravine extend in N-S direction parallel to the strike of the rock strata. In the lower reaches of this canyon like structure is filled with big rock blocks and boulders. The out cropping rock mass consists of closely to very widely spaced jointed gneisses and the test trench excavated at elevation 200 m MSL, has revealed the existence of major N-S trending fault zone running parallel to the ravine see figure No:5.

Scarce outcrops in the slopes of both abutments were generally formed by rather sound rock types and produced smooth ridges. Locally the rock mass was split up along foliation or joint planes producing block masses.

4.3 OVERBURDEN AND WEATHERING

Both flanks of the narrow valley at Randenigala dam site were covered by deposits of loose overburden which consist of big blocks, gravel and sand including a minor fraction of silt and clay towards depth. Fine grained material to a certain extent has been washed away. As a result the talus material has been made rather pervious and therefore stable.

The thick and only moderately foliated, high grade metamorphic rock sequence cropping out at the site has been affected by weathering over longer periods. The weathering enters along foliation planes and follow joints and fractures which separate the compact and massive bed rock into blocks in near surface zones. The decomposed rock zones were generally not thick and reached a few metres. Along fractured zones however, the decomposition of rock reached higher depths. In the geotechnical section of the dam site (see figure No:6), the unconsolidated over burden and completely decomposed rock i.e. residual soil are distinguished by different symbols though they do not differ much in geotechnical properties.

The investigations by exploratory drilling, pits adits and trench indicate significant different stages of weathering with regard to the fracturing of the bed rock. (Bed rock weathering is elaborated in section 5.1 in detail).

4.4 FOLIATION

The most striking structural element in the high grade metamorphic rocks prevailing at Randenigala site was foliation. The foliation planes, being the planes of separation between one layer of minerals and the next, reflect the former bedding planes. The spacing of foliation planes ranges between a few cm in the scarcely occurring gneissic metasediments and some tens of cm and even metres in the massive pyroxene amphibole gneisses.

Orientation of the foliation planes is NS with a strict maximum at W 353° N to N 5° E i.e. more or less perpendicular to the river. According to the joint measurements the dip of foliation varies between 80° towards E (downstream) and 82° W (upstream). Locally it shows a vertical position.

Such irregularities in dip of foliation may be explained by a primary lenticular sedimentary structure. Partially fault formation and consequent tilting during tectonic movements or secondary faults may be responsible for local deviating undulation features.

4.5 FRACTURED ZONES AND JOINTS

Joints are generally well developed in the different rock types occurring at Randenigala site, on the drill core samples and rock outcrops the observed average joint spacing within the massive rock masses was approximately 50 cm. On the other hand the joint spacing observed in the adits was noticeably less. Highly jointed zones of few metres thickness, striking W-E, were found on both abutments (i.e. in adits). According to the drill core samples and the test adits, such zones show a joint spacing of 10 to 15cm or even less. Extremely closely spaced joints are concentrated adjacent to E-W and N-S fault zones.

At the dam site the following three main joint sets could be clearly distinguished:

	Strike	Dip
Joint Set I	W 350° N to N 5° E	80°E to 82° W
Joint Set II	N 84° E to 96° S	84° S to 79° N
Joint Set III	W 345° N to N 13° E	64° W to 70° E

Joint set I represents the foliation planes. Joint set II reflect the main pattern of joints/fracture zones regionally observed in the project area with a strict maximum strike in the E-W direction. Their dip near vertical with steep angles to S or N.

The joint pattern III cuts the rock mass parallel to the foliation planes with more gently inclined angles towards either E or W.

Stress release fractures cut across the foliation and dip under small angles towards the valley axis. It could be observed that big blocks detached by such fractures from the rock mass in place show a creeping tendency causing open fractures. Such phenomena were confined to surface near zones along steeper inclined slopes.

Highly fractured zones were observed striking in both E-W and N-S directions. In the weathered zone the ultramylonitic fillings of highly fractured zones have been transformed to a soft clay as observed in the adits. When unaffected by weathering in shattered zones, tectonic breccia and ultra-mylonitic material were observed to be densely compacted and often showing a tendency of recrystallisation.

As shown in the Engineering geological map of the dam site (see figure No:5), within the foundation area of the proposed structures six E-W striking and one N-S striking major fracture zones have been observed.

4.6 ENGINEERING GEOLOGY OF THE TWO EXPLORATORY ADITS AND THE TRENCH.

In order to obtain direct information regarding the fracturing of rock, permeability and tectonic conditions in the central core area of the dam foundation, 75M deep, two horizontal adits were excavated. Azimuths of these adits were sub parallel to the strike of the rock foliation as shown in figure No:6. Both adits were excavated simultaneously during the North-East monsoon rainy season.

The adit at the left abutment runs beneath the terrace, situated in this location and crosses two fractured zones, which were filled with totally decomposed material. It could be observed that the decomposed zones diminish towards the bottom of the down stream wall of the adit. The adit shows further more fractured zones with a joint spacing between 5cm and 10cm (towards the end of the adit) with fresh hard rock inbetween joints. This adit crossed predominantly E-W striking fracture zones whereas a few N-S fractures was observed.

The adit at the right abutment was located within a depression and was expected to cross N-S striking tectonic features. (see figure No.5) Indeed this adit exposed many, very closely fractured zones striking in N-S direction. Weathering along the fracture zones was observed but total decomposition was not present.

In both adits a steady seepage of water through almost all the joints, occurring from the inlet to the end was observed. Further three small water springs were observed in the right bank adit, which functioned without change even in the dry season.

The exploratory trench on the left bank (see figure No.5) which crossed the fully exposed sound bed rock at depths varying from 1.5 to 4m.

On the western side of the stream the exploratory trench exposed a N-S striking about half metre wide zone with totally decomposed material. However, the width of this zone decreased towards the bottom of the trench as observed on the lateral walls, indicating the diminishing effect of weathering with the depth. Also similar, two other zones were observed on the eastern side of the trench.

5.0 ENGINEERING GEOLOGIC ASPECTS RELEVANT TO DAM FOUNDATION EXCAVATION/SURFACE TREATMENT AND SLOPE STABILITY.

5.1 GENERAL

At Randenigala, hard and thickly banded gneisses, occur which strikes favourably almost perpendicularly to the valley axis. Near vertical foliation dip (changing from down stream direction to upstream within the limits of the dam foundation in places) was also a favourable feature in respect of the stability of the foundation.

The over burden here comprise of talus material, rich in blocks of various sizes bigger than 1 M3 which were embedded in a rather pervious gravelly sandy matrix, poor in silty/clay content. This layer with depth grades into a more silty clayey material which represented the insitu decomposed residual soils. The latter residual soil mass contained a substantial amount of blocks/core stones of gneissic remnants and with depth gradually graded into highly weathered rock insitu i.e. bed rock.

Based on the investigation results the bed rock was subdivided into zones according to the degree of weathering by using the classification adopted by the International Association of Engineering Geology (Bulletin of IAEG 1981) as shown below.

- a) Decomposed material/rock
- b) Highly weathered rock
- c) Moderately weathered rock
- d) Slightly weathered rock
- e) Fresh rock

The highly weathered rock zones were observed to be a mass of splitted blocks insitu with decomposed material in between and lying on the moderately weathered rock zone, which grades into the slightly weathered rock where only fractures are oxidised, indicating percolation of ground water.

The morphology of the sound and fresh bed rock was uneven and showed an undulated surface (where exposed) with step like characteristics caused by the three main joint patterns and the stress release joints occurring in the foundation area.

The weathering of the bed rock was found to be highly dependant on the fracturing of the bed rock mass. As observed weathering has developed well along the densely fractured zones and further followed to depth along the joint planes which separate the bed rock into a blocky mass.

The thicknesses of different weathered zones (based on drill hole data) were found to be as given below:

<u>Left Abutment</u>			
Type of material		Thickness in m.	
		From	To
1.	Talus	2.0	5.1
2.	Decomposed material	3.0	8.5
3.	Highly weathered rock	5.5	14.00
4.	Moderately weathered rock	7.0	12.6
5.	Slightly weathered rock	13.4	22.8
6.	Depth to fresh rock from the ground surface	5.1	22.8

<u>Right Abutment</u>			
Type of Material		Thickness (m)	
		from	to
1.	Talus	0.0	4.9
2.	Decomposed material	3.0	12.7
3.	Highly weathered rock	4.0	18.7
4.	Moderately weathered	2.5	15.8
5.	Slightly weathered rock	9.0	19.0
6.	Depth to fresh rock from the ground surface	7.0	21.0

5.1.1 EXCAVATION OF THE DAM SHELL AREA

To place the dam's shell the requirement was to remove talus, decomposed material and in parts highly weathered rock where the degree of weathering was high resulting in a relatively higher decomposition within the highly weathered rock zone. (Sherard 1977). Most of excavation for the shell area was done with a D-8 dozer with the rock blade and subsequently with the ripper down to harder material. Where the rock levels changed abruptly, which would not permit proper rock fill compaction, protruding rock blocks were blasted to establish a flat surface.

Prior to the final excavation work the foundation depth for the shell area was expected to be identical with the upper border line of the highly weathered rock zone as given in figure No. 6-geotechnical section. Weathered bed-rock which fulfill the technical requirements for the shells of the rock fill dam was judged to be encountered in an average depth of 7-8 m generally, but adjacent to

fracture zones and in fracture zones the depth was expected to increase considerably.

5.1.2 EXCAVATION OF THE CORE TRENCH AREA

The trench of the impervious core was judged to be about 9-10m below the shell area in order to place the impervious clay core and adjacent filters on technically acceptable moderately to slightly weathered rock which can be rendered impervious by cement grouting. The bottom of the core trench was required to be an even and a flat surface, so as to facilitate perfect earth compaction. As the bed rock was frequently splitted by E-W and N-S striking fractures into rectangular blocks, to obtain a technically acceptable core trench bottom controlled blasting was adopted. (Sherard 1977)

5.2 DAM FOUNDATION- SURFACE TREATMENT

5.2.1 SHELL AREA

Results of investigations clearly indicated that many highly fractured zones with decomposed material cross the shell area in the N-S as well as E-W directions. These zones were excavated to a depth three times of their widths (William 1957) and consequently were filled with coarse filter material or rockfill (where appropriate and the width permitted) in layers and was mechanically compacted, till the fill reached the adjacent bed rock level.

5.2.2 CORE TRENCH

The highly fractured zones with decomposed material encountered in the core trench and filter zones were excavated similarly to the ones in the shell area and were filled with concrete.

In the river section the canyon filled with alluvial material encountered in the limits of the core trench was too excavated to the bottom and was filled with concrete.

In the shell area the alluvial fill of the canyon was replaced with compacted rockfill.

5.3 SLOPE STABILITY

The natural slopes of the valley covered by thick vegetation was found to be stable with inclinations varying 20° to 40°. These slopes covered by loose over burden which consists mainly of sand, gravel and blocks were rather pervious. Considering the constitution of slope material, excavated earth slopes of height less than five metres were considered to be stable with an inclination of 45°, as indicated by the already excavated slopes, in

near by areas. If the height increases the slope had to be flatter or if not supported.

The crests of the ridges were commonly split-up into big blocks which tend to produce rock falls of limited volume. Prior to construction such rock masses were required to be removed.

Joints and fracture zones crossing the valley perpendicularly and dipping predominantly near vertical were not harming the overall stability of the foundation areas. The densely fractured zones striking parallel to the river detached rock portions from the bed rock during excavation. Therefore stabilization measures appropriate to the location were for seen.

6.0 CONCLUSIONS

- I Randenigala project area is entirely made up by rocks of the Precambrian highland series represented by metamorphosed sediments (gametiferous gneisses, quartz feldspathic gneisses, granulites quartzites and marbles) and charnockites. Alluvial river deposits (sand & fine gravel) occur in scattered isolated locations in small quantities. Terrace deposits (clayey, gravelly) exist within Randenigala reservoir area in relatively flat ground at elevations between 10m to 30m from the riverbed. Talus of varying dimensions from fine grained to large boulders were observed every where on the slopes of the valley.
 - II The project area is characterised by a regular pattern of approximately N-S trending folds, consisting of:
 - a) Rantembe syncline geo-structural elements
 - b) Fold and shear zones between Randenigala and Serasuntenna with a number of folds anticlines and synclines of secondary order
 - c) Belihul Oya syncline.
 - III Geomorphologically at Randenigala dam site the river section is narrowest compared with up stream as well down stream parts of the valley, with a river bed width of about 75m. Here the river has carved it's bed into hard rock sequence of pyroxene gneiss (charnockite) granulites and quartzitic gneiss, with a canyon of about 8m deep and filled with alluvial deposits.
- The right abutment rises smoothly up to 240m M.S.L. with an inclination of about 30° up to elevation 400m MSL.
- The left slope rises with an inclination of 28° up to elevation 184m MSL grading into a 13° inclined terrace reaching 200m MSL.

IV The foliation planes with a spacing between them, from a few centimeters, strike in the N-S direction more or less perpendicular to the river. These planes dip at angles varying from 80° to East (D/S) and 82° to West (U/S).

V At the dam site joints were very well developed in bed rock and the below shown three main joint sets could be clearly distinguished.

- 1) Joint Set I W 350N to N 5° E 80° E to 82° W
- 2) Joint Set II N 84° E to E 96° S 84° S to 79° N
- 3) Joint Set III W 345° N to N 13° E 64° W to 70° E

Joint set I represents the foliation planes. Joint set II was the main pattern of joints/fracture zones regionally observed in the area. Joint pattern III cuts the rock mass parallel to foliation at gentler angles.

Joint patterns II and III are of tectonic origin formed during the formation of folds and shear zones due to regional tectonic activities.

VI There are six E-W striking and one N-S striking major fracture zones within the Randenigala Dam foundation.

- According to the degree of weathering the geological profile of the dam side can be divided from top to bottom

- a) Over burden
- b) Decomposed material/residual soils
- c) Highly weathered rock
- d) Moderately weathered rock
- e) Slightly weathered rock
- f) Fresh rock.

The weathering of bed rock was highly dependant on the degree of fracturing of the rock mass. Weathering of bed rock to the degree of complete decomposition had penetrated along the densely fractured zones, then deeper along the joint planes which separate the bed rock.

VII For the placement of rock fill shell area was excavated to a depth of rippable highly weathered rock ensuring a flat slope facilitating normal mechanical compaction of rock fill material.

VIII Excavation of the core trench, for the placement of clayey material and filters was done to reach moderately or slightly weathered rock which could be made impervious by cement grouting.

IX Both in the shell area and the core trench where bed rock undulations, were encountered, which would

not facilitate proper compaction of material, were removed by control blasting.

X Highly fractured zones with decomposed material encountered in the shell area were excavated to depth, thrice the width of such zones. Consequently were filled, in layers with filter or rock fill material, depending on the width of the zone and was mechanically compacted.

XI Such zones encountered in the core trench, were excavated similarly to in the shell area but were filled with concrete.

XII The canyon encountered in the river section, within the core trench was cleared of all loose alluvium and was filled with concrete whereas the loose alluvium in the shell area was replaced with compacted rock fill.

XIII Joints/fracture zones crossing the valley perpendicular to the river with near vertical dip angles were basically not having any detrimental effect on the over all stability of foundations. However, the main joints/fracture zones striking E-W did detach portions of rock from the bed rock mass during excavation and had to be stabilized with mainly anchors.

XIV Both adits (on left bank and right bank) clearly indicated a steady percolation of ground water into the adits during the rain proving the necessity of an extensive grouting programme for the dam foundation i.e. core trench area. For this purpose to evaluate the permeability of the rock mass under the core trench a separate investigation programme was undertaken at the initial stage of the construction period.

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