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Geotechnical Investigation of Ban Koum Dam Site, LPDR-Thailand Boarders

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Abstract

The Ban Koum dam site is located in Ban Khamtu, Khong Sedone district, Saravan province of the Lao People's Democratic Republic, covering an area of latitudes 15°26’ 36’’ and 15°27’ 43”N and longitudes 105°35’ 04” and 105° 36’ 47’’E. The center line of the dam extends across the Mekong River from the East in Ban Khamtu of LPDR to the West in Ban Tha Long of Thailand. The dam is also a tourist attraction. The geotechnical investigation undertaken consists of geological mapping for engineering purpose, subsurface drilling, and construction materials assessments. Rock mass of the center line of the dam is mainly conglomeratic sandstone, slightly weathered rock with approximately 40-60 MPa of uniaxial compressive strength, which could be regarded as a good rock condition. The majority discontinuities show the strike and dip of the sandstone bedding in the range of 175 º-195 º /5 º-10º and the joint values of 270 º-295 º /70 º-85 º N and 175 º-192 º /65 º-85 º W. The Lugeon values from the ground surface to 15 m depth of the rock mass are 5-33 Lugeon. From the depths of 15-50 m, the Lugeon values decrease to 0-8 Lugeon. Impervious soil for the earth embankment is Lean clay (CL) and Clayey Silt (ML) with the total amount of 1,400,000 cubic meters. The proposed burrow area is 1.5-2.5 km from the left abutment of the dam in north direction. The properties of the coarse aggregate and sand have met the criteria of the concrete aggregate. Cement grouting is required to improve the

shallow depth of the rock mass and to fill the potholes at the rock surface of the rapid.

Keywords: Rock Mass, Lugeon, Geotechnical Investigation of Dam

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Introduction

Mekhong River Committee (MRC) proposed the Ban Koum Dam, a hydropower project, for the development of the Lower Mekong Basin since 1970(Montri, 2008). It lies mostly between latitudes 15°26' 36" and 15°27' 43"N , and longitudes 105°35' 04" and 105° 36' 47''E as shown in Fig. 1. The proposed hydropower project is located in Ban Khamtu, Khong Sedone District, Saravan Province, Lao People's Democratic Republic (LPDR). The investigated area was about 10 square kilometers. The right side of the dam site was a part of PhaTaem National Park of Thailand. The center line of dam and the adjacent rapid areas are the tourist attractive site, namely "soundpan boak"(20,000 potholes shown in the river beds at the rapid). Fishing is common in the river. The local people of the two countries use the boats as a major transportation and for communication. Mekong River banks present the rapids and mountain ranges which covered by Deciduous Dipterocarp Forest.

Geotechnical investigation of the Ban Koum dam aims to understand the ground characterization, and to estimate the quantity and the basic quality of the construction materials. It had been carried out in December 2012. The investigation was limited as a preliminary study. The shear strength properties of the construction materials had not been established. There was no reference point obtained by the ground surveying, then the reference points of the bore holes and the mapping locations were adopted by the GPS. As the right bank of the dam was covered by Pha Taem National Park, the investigation agreed to follow the law of National Park of Thailand. Then, the representative drilled holes and the borrow area had been performed at the center line of the dam and at the left side of Mekong River, located in LPDR. Geological mapping had been carried out at the out crops, especially at the center line of the dam. Construction materials had been preliminary investigated by using borrow pit technique for soil investigation, by sampling techniques at the sand mines and at the rock quarries for aggregate.

Figure 1. *Location Map of the Ban Koum Hydropower Project at Mekong River, Boarder of Thai-Loa LPDR*

Methods of Investigation

Methods of investigation were based on their objectives which comprised of geological mapping, subsurface drilling and construction materials assessments, described as the following.

Methods of geological mapping; there were the desk study and field work. The desk study consisted of the study of the existing information and preparation of the field work equipments and accessories. The geological map was duplicated from 1:50,000 topographic map of the Royal Thai Survey Department (Royal Thai Survey Department, 1999). Google Earth (free edition) was applied for the route traverses planning. The value of the grid reference points (UTM) obtained by GPS was checked and defined by the value gained by the satellite images of Google Earth and the value of those from the topographic map. Rock mass was preliminary assessed by the Geomechanics System of Rock Mass Rating, RMR (Bieniawski, 1979). The out crops were described and checked their rock type, discontinuity, groundwater condition and the uniaxial compressive strength determined by Schmidt rebound number. Soil unit was classified by geomorphology and by Unified Soil Classification System. The geological map was produced in 1:10,000 scales. For seismicity of the dam site, reviewing on the existing information was considered. There was no device to measure an earthquake at the dam site.

Methods of subsurface investigation; rotary drilling machine and sampling system were applied for obtaining the rock core sample and the standard penetration test was carried out to determine the N-Value of the soil layers. There were two drill holes, DH.1 and DH.2, conducted at the centerline of dam which located at the left bank of the Mekong River. DH.1 and DH.2 presented the holes depth of 50 meters and 20 meters. The representative core samples showed the characterization of the dam foundation both the soil and rock mass. The in situ tests of the soil layers were permeability test and standard penetration test which based on the standard methods of USBR-E18 and ASTM D 1586 - 96. Soil samples were classified for engineering purposes as ASTM D 2488 - 96. ASTM D 2488 - 96 was use as the visual-manual procedure for description and identification soil in the field (ASTM, 1996). The SPT and permeability were carried out every depth interval of the soil layers. The Lugeon test was performed at the rock mass at the 3 meters length of the depth interval. Rock core sample was well preserved in the core box. The rock core was logged and described the rock type, RQD and joint characterization. Shear strength and deformability of the rock mass at the dam foundation had not been studied.

Methods of the investigation of the construction materials; the purposed borrow area covered about 500,000 square meters. It was located about 2 km far from the left abutment of the dam in North. The rectangle borrow area was divided as a grid system. Four reference points and 30 bore holes were determined by GPS. Soil sample from the auger was classified base on USCS visual-manual procedure as ASTM D 2488 - 96. Four test pits were randomly conducted at the representative area. Representative soils samples were randomly checked the dispersive clay by the crumb test. Disturbed samples from the test pits were taken to the laboratory for determination on the basics soil properties, USCS classification, dry density and optimum moisture content. For the others construction materials, rock, coarse aggregate and sand, the samples were obtained from the quarry and sand pits of the local area for testing their properties, i e uniaxial compressive strength, specific gravity, absorption, percentage of loss by solution and by Los Angeles test. The number of the tested sample was considered by design engineer and the relevant persons.

Ground Characterization

For engineering purpose, geology, subsurface ground and construction materials of the dam site were reported and discussed as the following.

Geology; Geologic map of the the Ban Koum Hydropower Project was shown in Fig.2. Sandstone is mostly common found in the dam site which supported by the 1:1,000,000 geological map of Kampuchea, Laos and Vietnam (General Department of Geology, 1988). There were 4 rock units covered the study area which described as the following.

Qa unit was the sediments deposits. It had been found at the river bank and creek. It consisted of sand predominantly. Gravel and non to low plastics silt and clay were found. For engineering purpose the Qa unit was classified by visual-manual procedure as Clayey-Silty Sand (SC-SM) and Poorly Graded Sand (SP). It was loose to medium dense sand and slightly moist to wet.

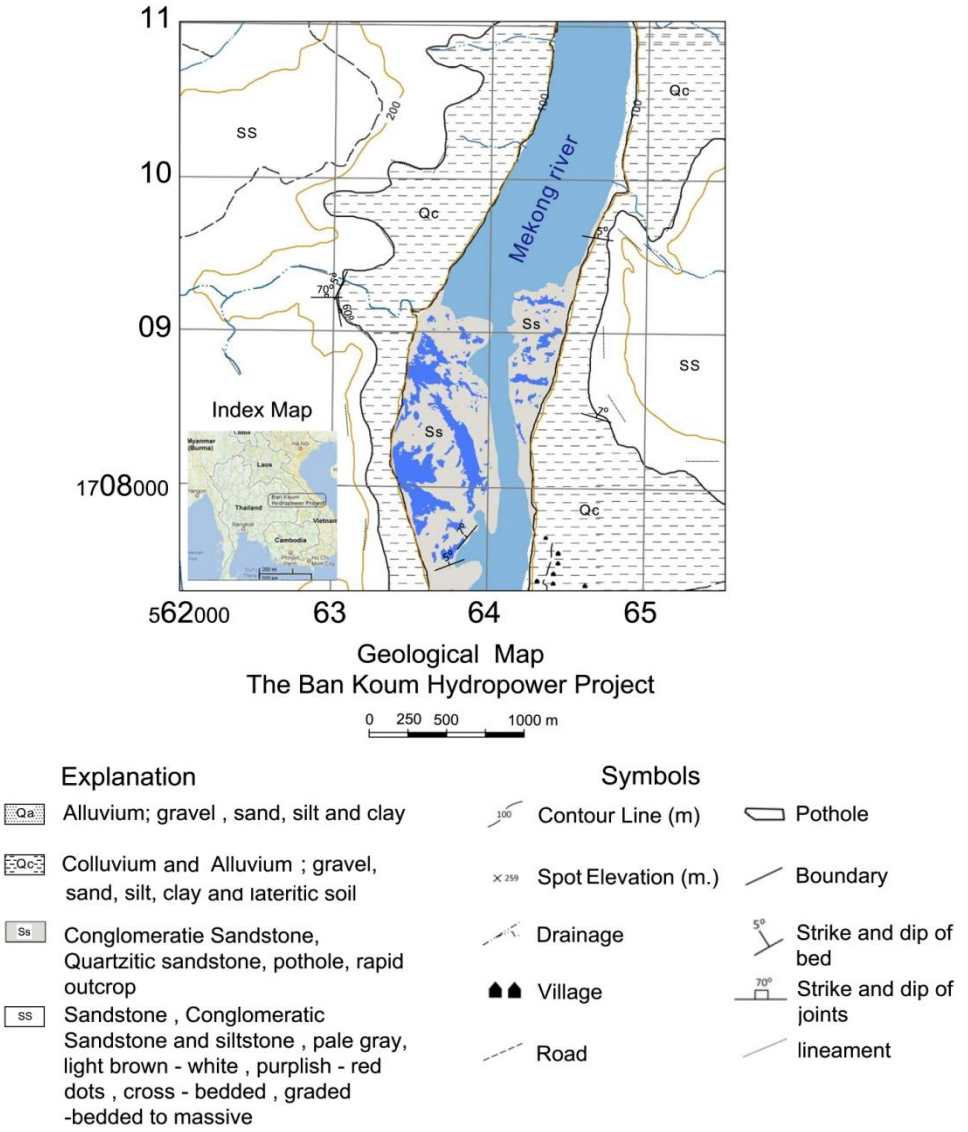
Qc unit was the sediments deposited at the undulating area, hill slope to slope toe and creek. It was mainly consisted of silt and clay. Gravel and sand had been mixed in the Qc unit, by the ratio of 10 % by weight. For engineering purpose the Qc unit was classified by visual-manual procedure as Lean Clay (CL), Clayey Silt (ML) and Sandy Clay with Gravel (CL). It was medium hard to hard clay with dry to slightly moist.

SS rock unit covered the mountainous areas at the right and left abutments, was depicted as sandstone, conglomeratic sandstone and siltstone; pale gray, light brown to white, purplish - red dots, cross - bedded, graded - bedded to massive rock. The rock bedding is gentle dip (about 5º - 15º) through northwest - west with the dip direction of 290 º - 315 º. The majority joint was in same direction of Mekong River, 350 º- 30 º with vertical dip. Minority joints showed the values of strike and dip as 250º - 280 º /5 º- 10 ºNW-N, 120 º - 150 º /60 º - 80 º SW and 25 º - 40 º /70 º - 85 º. Schmidt rebound number of sandstone showed as 40 - 45 numbers which could be estimated the uniaxial compressive strength of sandstone as 40-50 MPa. Sand grains of sandstone were poorly sorted with was moderate to well cemented. Siltstone was moderately to highly weathered, and showed the low to moderate degree of hardness compared with sandstone. Rock mass presented competent and incompetent bedding. Weathering condition in rock mass was slightly to moderately degree of weathering. Joint spacing of the rock mass was varied from 10 cm to 10 m. Rock mass was highly jointed to massive or large block rock. Open joint and clay filled joint were found at the rock surface. The tight joint and 1-5 mm opened joint were typically found. Water seepage and spring have not been found in the rock mass at the project area. Soi Sawan Waterfall was recognized and was located far 2.5 km from the center line of dam in North West. In general, rock mass rating value showed good condition. The shear strength properties of the rock masses, estimated by RMR, presented the internal friction angle and cohesion as 35 º- 45 º and 300 - 400 kPa.

Ss rock unit covered the rapid at the Mekong River. It comprised of conglomeratic sandstone and quartzitic sandstone, white to light brown, various sizes of the pot holes on rock surface. Strike and dip of the sandstone bedding was 175 º - 195 º /5 º - 10 º. Majority joints were vertical joints, with the strike and dip of 270 º -295 º /70 º - 85 º N and 175 º - 192 º /65 º - 85 º W. The uniaxial compressive strength of conglomerate sandstone and quartzitic sandstone estimated from the Schmidt rebound number was about 100 MPa, showed a high value compared to SS rock unit's uniaxial compressive strenght. Sand grains are well cemented and sorted. Joint spacing of the rock mass was varied from 20 cm to 300 cm. Joint persistence was in North-South and NWW-SEE. The depth of pot holes was 10 cm- more than 5 m. The groundwater seepage has not been found. The rock mass was rated as a very good rock

mass. The shear strength properties of the rock masses, estimated by RMR, presented the internal friction angle and cohesion as more than 45 º and more than 400 kPa. The centerline of dam shows a very good rock condition. The upstream part of the dam is a rapid, known as Soundpan Boak (20,000 pot holes). The pot holes can be fulfilled by the dental grout or replaced by concrete.

Figure 2. *Geologic Map of the Study Area*



Subsurface Geology; the subsurface ground obtained by 2 drill holes, located at the left abutment of the dam was described as the following.

-**The centerline of dam**; rock of the subsurface comprised of sandstone interbedded with thin layer of siltstone at the depth of 28 - 29 m and at 36 - 37 m. Sandstone texture was classified as conglomeratic, pebbly and muddy sandstone, white-light brown and pale maroon for muddy sandstone and siltstone. The degree of weathering of sandstone and siltstone presented as

slightly weathering and moderately weathering. Sandstone was medium hard to hard rock. The estimated uniaxial compressive strength was 80 MPa in average. The average value of the number of joint per meter was 4 - 8 joints per meter. RQD value was in the range of 70 - 80% for the depth of 0 - 15 m, and in the range of 80 - 90 % at the depth of 15 - 50 m. The Lugeon value of rock mass at the depth of 0 - 15 m was 5 - 33 Lugeon. From the depth of 15 - 50 m the Lugeon value was decreased as 0 - 8 Lugeon. Tight joints and clay filled joints were mainly found.

- The left abutment of dam; there were 3 layers of soil covered in the left abutment of the dam in 6 meters think. From surface to the depth of 3.5 m was stiff silty caly(CL); low to medium plastic fines, brownish black, with some sand and moist to wet. At the depth in between 3.50 - 5.85 m was clayey sand and silty sand (SC-SM), loose to medium dense, low plastics fines, reddish brown, moist. The thin layer of lateritic soil which classified as clayey gravel (GC) and as the residual soil of sandstone was found at the depth of 5.85 - 6.35 m. The soil formation was impervious-semi impervious soil. Soil layers were stiff clay layer and medium dense sand layer. Sandstone interbedded with muddy sandstone and quartzitic sandstone had been found at the depth of 6.35 - 20.00 m, at 10.60 -13.50 m and at 16.30 -17.30 m, respectively. It was moderately weathered rock with medium hard – hard rock. The estimated uniaxial compressive strength was about 50 MPa. The average value of RQD was 95%. The number of joint per meter was 2-4 joints per meter. Joint was mostly tight joint. The Lugeon value was 1.3-7.2 Lugeon.

The rock mass characterization of the surface was quite different from subsurface data. The surface rock out crop showed the joints persistence in the direction of N-S and NE-SE. Those joints showed steep-vertical dip, implied the water flow path which was similar to the Mekong River flow. To prevent the harm from seepage after dam construction, detail investigation on water pressure test should be carried out in detail stage of the study.

Seismicity Information

There was no report about the earthquake at the dam site and the adjacent area. The Korat Platuea region closed to the dam site was considered as non to low seismicity zone, no evident of active tectonic fault (Thanu Harnpattanapanich and Anchalee Luddakul, 2011). The USGS reported that on Monday22, October 2012 about 20:41:39 (Local time of Vietnam) at the reference point of 15.353 º N and 107.99 º E, the 4.1 Earthquake magnitude occurred at 10 km depth was reported (USGS, 2012). The location was at Lao-Vietnam boarder which far 350 km from the dam site in East. In May 16, 2007 the 6.1 M of Earthquake had been occurred at the depth of 38 km which was detected at 20.47 º N and 100.7 º E, south of Vientien, LPDR. It was about 600 km far from the dam site in Northwest (USGS, 2007).

Construction Materials

Investigation of the construction materials, riprap, coarse aggregate, fine aggregate and impervious soil had been carried out at the dam site and the adjacent area. Rocks as a riprap, coarse aggregate, and fills were randomly sampling from the rock samples of the drilled holes for uniaxial compressive strength assessment. As a large amounts of rock materials is required for the dam construction, to choose the rock quarry located near the dam site was required. The natural gravel materials obtained at the sand mines and pits, located near the dam site were collected and tested. The 1" and ¾" sizes of the aggregates obtained from the rock quarry located 30 km in northwest of the dam, were tested. The aggregate testing result was shown in Table1. The natural river gravel, 1" and ¾" sizes of the aggregates showed the average apparent specific gravity (Gs) as 2.638 - 2.698. The value of Absorption of the natural gravel, 1" and ¾" sizes of the aggregates presented as 0.877 %, 2.452 % and 2.164%, respectively. The value of the abrasion loss of the natural river gravel, 1" and ¾" sizes of the aggregates were 25.5%, 33.9% and 33.6 %, respectively.

Table 1. *Aggregate obtained from the representative quarries*

Tested Results\Materials:	Nat. River Gravel	Aggregate 1"	Aggregate 3/4"
Gradation			
2"-1" (%)	6.7	0	0
1"-#4 (%)	86.7	99.5	98.9
Sand (%)	18.3	0.1	0.5
Fies (%)	0.1	0.4	0.6
Aver. Bulk Gs (Oven-Dry)	2.578	2.507	2.55
Aver. Bulk Gs (SSD)	2.601	2.569	2.605
Aver. App. Gs	2.638	2.671	2.698
Absorption (%)	0.877	2.452	2.164
Loss by solution (%)	0.886	8.218	6.02
Loss by abrasion (%)	25.5(Grade A)	33.9(Grade A)	33.6(grade B)

Fine aggregate, sand, as a filter and for a concrete material was obtained for testing, the result of testing was given in Table 2. Poorly graded sand (SP) with about 0.4% of fines contained, showed the value of fines modulus as 1.4. The average apparent specific gravity was about 2.685. The percentage of absorption, plastic fines and loss by solution of sand was 1.34%, 95.1% and 0.045%, respectively. Organic matters and fines contained in sand materials were small amount. It can be used for concrete. Filter criteria has not been designed for this stage of the study.

Borrow area was located in north of the dam site or at the up-stream area as shown in Fig. 3. During investigation, boat trip was used. There was no local road accessed to the borrow area. The borrow area was low intensity of the big trees and was covered by grasses and bamboo. The topsoil was about 0.3 m thick. The average depth of soil layer for construction material is about 3.6 m.

Usage of hand auger for boring, sometimes hit boulders and gravels. Soil layers were mostly dry to moist and hard. Testing results of soil samples from test pits had been tabulated in Table 3. Soil was classified and was estimated the quantity as shown in Table 4.

Table 2. *Result of the Testing of the Representative Sand*

Tested Results\Material	Sand
USCS	SP
F.M.	1.457
%Fines	0.4
Average Bulk Specific Gravity (Oven-Dry)	2.592
Average Bulk Specific Gravity (SSD)	2.627
Average Apparent Specific Gravity	2.685
Average Percent of Absorption (%)	1.335
Plastic Fines, sand equivalent test (%)	95.1
Organic Content (Matter), Color Scale	Organic Plate No.2
Sodium Sulphate Solution Weighted Percentage Loss(%)	0.049

Figure 3. *Location of Borrow Area*

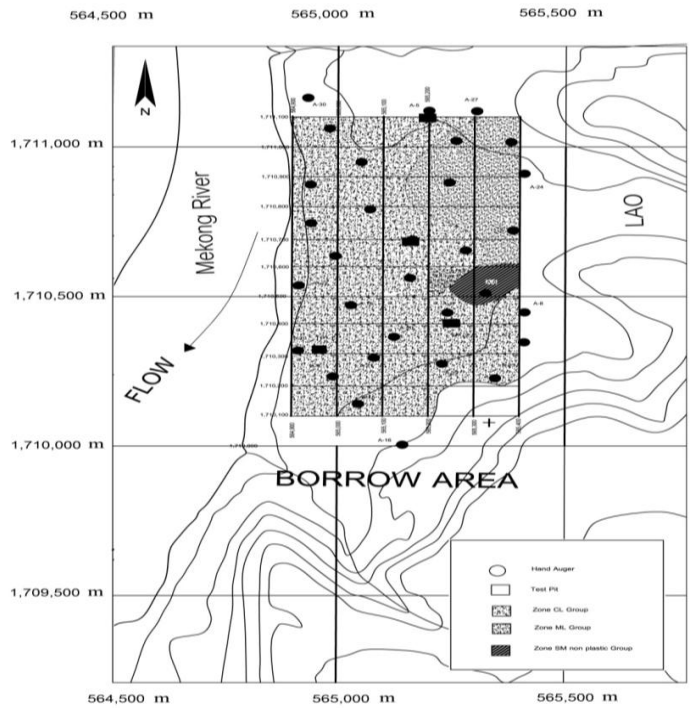


Table 3. *Index Properties of Soil from Laboratory and Visual Eyes classification*

Categories\Soil Group	CL	ML	SM
Gravel (%)	0-10	0-10	0-10
Sand (%)	8-10	10-30	70-85
Fines (%)	60-90	60-80	15-30
Plastic Limit (%)	15-20	non-low	NP
Liquid Limit (%)	30-40	-	-
Plastic Index (%)	16-20	-	-
Maximum Dry Density g/cc	1.35-1.58	-	-
Optimum Moisture Content, OMC (%)	15-20	-	-
Specific Gravity , Gs	2.64-2.69	-	-
Natural Water Content , Wn(%)	4-8	dry to moist	dry to moist
Soil Classification;	Lean Clay, Silty Clay	Clayey Silt	Silty Sand
Notice	Laboratory	Visual Eyes.	Visual Eyes.

Table 4. *Impervious Soils and Silty Sand from the borrow area*

Borrow No.	Total Cubic meter	CL Cubic meter	ML Cubic meter	SM(non-plastic) Cubic meter
1	1,518,333 (100%)	911,000 (60%)	576,967 (38%)	30,367 (2%)

Construction materials presented the impervious soil comprised majority of Lean Clay (CL) and Clayey Silt (ML). Lean clay was about 60 % of the total amount of the investigated soils. Table 2 Sand obtained from the representative sand pit was about 911,000 cubic meters. The dry density of the compacted lean clay and the optimum of moisture content presented as 1.3-1.5 g/cc and 15%-20%. Clayey silt (ML) has been found with the amount of 576,967 cubic meters which was about 38 % of the total amount of soil for construction. Lean Clay and Clayey Silt were classified as impermeable soils, presented about 1,480,000 cubic meters. Dispersive clay has not been found. The shear strength property of compacted lean clay is needed to be performed in the further study. Silty sand (SM) was found as pocket sand at the creek and

at the abandoned swamp. There were variation of soil types due to limitation of test pits and geological condition. Detailed investigation and design of the construction materials for the project were needed to be carried out.

Conclusion and Recommendation

The result of geotechnical investigation of the Ban Koum Hydropower Project could be summarized and drawn the recommendation as the following.

- Rock mass of the ground surface of the center line of dam was conglomeratic sandstone, slightly weathered rock with about 40 - 60 MPa. It was rated as good rock condition. The majority discontinuities showed the strike and dip of the sandstone bedding as 175 º - 195 º /5 º - 10 º and of the joints as 270 º - 295 º /70 º - 85 º N and 175 º - 192 º /65 º - 85 º W. Rock mass at the left and right abutment of the dam was sandstone rated as good rock. North-South and Northwest direction of the discontinuities presented the continuous and persistence of joints which groundwater could be easily flow through these joints direction. To block or to reduce the seepage force is required for protection of the dam and appurtenance structures.

- Subsurface of the center line of the dam (Left bank of Mekong River) was sandstone interbedded with siltstone. The rock mass was in very good condition. Tight joints and clay filled joints were mainly found. The Lugeon value from the ground surface to 15 m depth was m was 5 - 33 Lugeon. From the depth of 15 - 50 m the Lugeon value was decreasing as 0-8 Lugeon. The rock mass at the depth of 15 - 50 m of the dam foundation was rated as a very good rock. For the left abutment of dam the soil layers of CL, SC-SM and GC was about 6.35 m in thick. It was impervious to semi impervious soil. Sand pocket and lens and gravel were found. Rock mass at the abutment foundation was sandstone rated as good rock. The Lugeon value of rock mass was 1.3 - 7.2 Lugeon. The detail investigation at the center line of dam and the appurtenance structures was required to assure the permeability of the rock mass, and to check the pervious layer soil deposits at the abutments.

- There was no report about the earthquake at the dam site and the adjacent area, the dam site was considered as non to low seismicity zone, no evident of active tectonic fault.

- Soil as impervious embankment material was Lean clay (CL) and Clayey Silt(ML) with total amount of 1,400,000 cubic meters. The properties of the coarse aggregate and sand had been met the criteria of the aggregate for concrete. The geotechnical investigation in detail design stage was required.

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