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Engineering Geological Characterization of Proposed Sabaloka Dam Site

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Abstract

This study was carried out to investigate the selected site for the proposed hydropower dam that located at the six cataracts in the River Nile State, Sudan. The study based on the use of the enhanced landsat imageries and the structural analysis of the fractures in the investigated site. The River Nile bisects the Sabaloka volcanic plateau at the proposed dam site. The exposed rocks are Agglomerate, Rhyolite and Ignimbrite. The proposed dam axis is located in the relatively less fractured Agglomeratic rocks. The main fractures trends are NW and NE directions and cut, respectively the western and eastern flanks of the dam axis. Three boreholes were drilled at the proposed site by rotary drilling, geotechnical analyzes, and observation the results of the three borehole is typically matched in lithology it appears silt sand and agglomerate but there are some different in the depth of agglomerate

Keywords: Boreholes, Geotechnical Analyzes , River Nile, Sabaloka dam, Sudan

Introduction

The proposed dam is located at the Sabaloka igneous complex on the sixth cataract of the River Nile. The storage capacity of the proposed dam is about 4000 million cubic meters, its lake extends southward to about 15 km and the water level is expected to rise 6 to 10 meters. The Sabaloka dam is proposed for multi-purposes, mainly for hydro-power generation and irrigation in addition to help in minimizing the siltation for the Merwe dam to the north. Moreover, it will represent an excellent habitat for fisheries in the lake behind the dam. The main objective of this study Geotechnical treatments needed to identify the geotechnical properties of soil and rock foundations

The Study Area

The Sabaloka area is located in the southern part of the River Nile State between longitudes 32° – 32° 30" and latitudes 16° 15" – 16° 30" about 80 Km north of Khartoum (Figure1). This area is characterized by semi desert climatic conditions with average annual rainfalls range between 50 – 100 mm. The highest daily mean temperature is about 43°C during the summer period from May to October, and the lowest mean temperature is about 16°C during winter period from December to February. The Sabaloka area being one of the most important Pre-Cambrian exposure in Sudan, attracted the interest of many geologists such as; (1958) Kroner et al (1987). Dawoud & Sadig (1988) and Almond & Ahmed (1993) [1-4]. to study different geological aspects of this area. Geologically, the area forms an inlier that consists of different type of rocks ranging from metamorphic (Gneiss and migmatites) through igneous (Sabaloka igneous complex) to sedimentary (Cretaceous sandstone). It represents a continental slope of the ancient continent during the Pan African time, Kroner et al. (1987) [2]. By early Paleozoic time the basement had been tectonically stabilized and reduced by erosion to a peneplain. The igneous activity; exemplified by the Sabaloka Igneous Complex is built up of felsic volcanoes which rise above the gneissose peneplain. The Sabaloka igneous plateau is consisted of basaltic lavas, agglomerate, rhyolite and ignimbrite, (Figure 2).

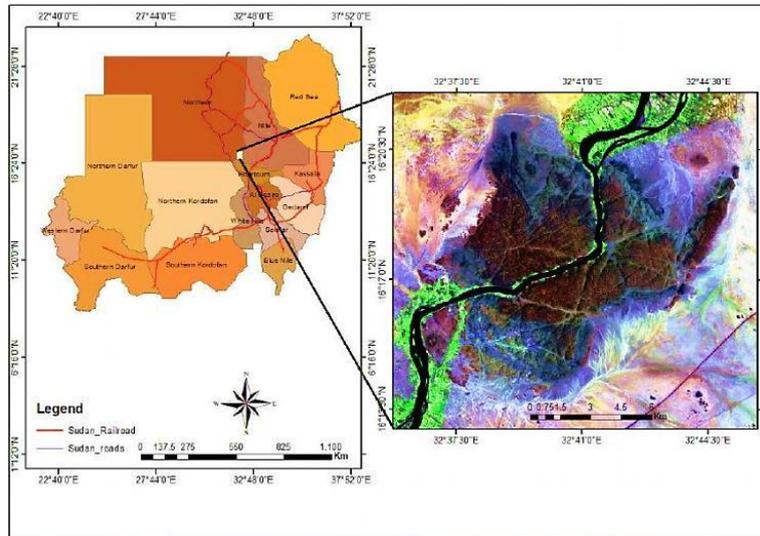


Figure 1: Location Map of the Study Area

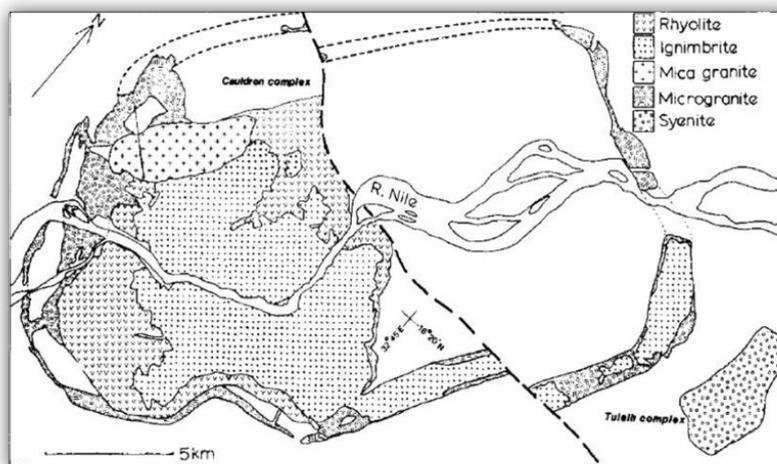


Figure 2: geological sketch map of Sabaloka igneous complex by (n. B. W. Harris, h. J. Duyverman & d. C. Almond 1993)

The aim of this study is to investigate the suitability of the suggested site for dam construction based mainly on the geological point of view using remote sensing, lithological identifications and structural analysis.

Drilling Work Introduction

Geotechnical work is normally performed to know the engineering geological properties of the site materials. This will help in the project design by used field tests (Stander Penetration Test, Permeability, Strength, rock Stability, Water Saturation, Porosity and Layer thickness) were performed in the borehole. Three boreholes were drilled at the proposed site by rotary drilling, and geotechnical analyzes and tests were conducted on them, and the results were as shown below.

Classifications Of Some Discontinuity Features

Discontinuity is any structural or geological feature that changes or alters the homogeneity of a rock, which may be technically joints, bedding planes, minor faults, or other surfaces of weakness such as cleavage and schistosity planes. It excludes major faults, since they are considered as structural regions of their own.

Classification of joint alteration and weathering			
Clean or unfilled joints		Filled joints	
A	Healed or welded joints	G	Friction materials (silt, sand, etc.)
B	Unweathered, fresh joint walls //no filling	H	Hard, cohesive materials (clay, talc, chlorite)
C	Slightly altered joint walls (coloured, stained)	I	Soft, cohesive materials (soft clay)
D	Altered joint wall (no loose material)	J	Swelling clay materials
E	Highly altered // coating of friction materials (silt, Sand, etc.)		
F	Decomposed // coating of cohesive materials (clay, Chlorite, etc.)		

few centimetres, see Figure 4.1 The two main groups are joints and weakness zones. These are described in the following:

- Joint is a discontinuity plane of natural origin along which there has been no visible displacement. Joint is here used as a term for break, fracture, crack, as seen in Figure 3
- Singularity is a small weakness zone or a seam.
- Weakness zone is a part or zone in the ground in which the mechanical properties are significantly lower than those of the surrounding rock mass. Weakness zones can be faults, shears / shear zones, thrust zones, weak mineral layers, etc.

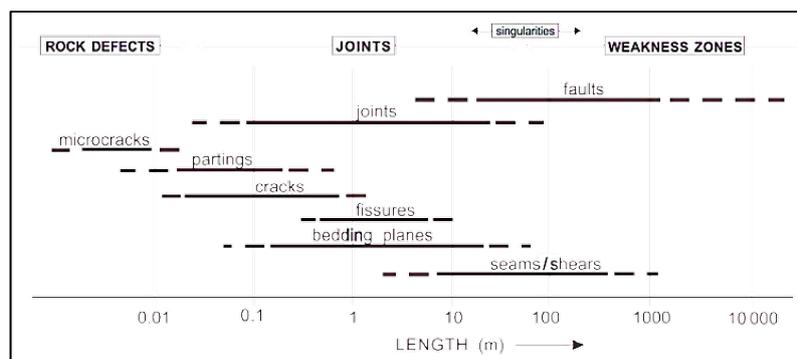


Figure 3: The Main Types Of Discontinuities According To Size (Revised From Palmström, 1995).

Condition of discontinuities includes roughness of the discontinuity surfaces, their separation (distance between the surfaces), their length or continuity (persistence), weathering of the wall rock of the planes of weaknesses, and the infilling (gouge) material. Some of these are classified in the following

Classification Of Joint Surface Smoothness

Classification of RQD		
Term		RQD
A	Very poor	< 25
B	Poor	25-50
C	Fair	50-75
D	Good	75-90
E	Excellent	90-100

RQD is mainly a measure for the degree of jointing, originally linked to drill core logging. Although RQD is a quick and inexpensive index, it has limitations such as the disregarding of joint orientation, tightness, and gouge (infilling) material. Consequently, while it is a practical parameter for core quality estimation, it is not sufficient on its own to provide an adequate description of a rock mass.

Table 4.4 : Classification of Joint Alteration and Weathering

Classification Of Joint Surface Smoothness

Table 4.7 : Classification of RQD

Result of The Drilling Work Borehole number (412)

This borehole was drill in 2018 with total depth 35meter by rotary drill with inclination 90 degree in Misikit island area, for identification of subsurface geological formation and engineering properties.(Total depth 35.00 meter).

Geological Characteristic

- 1-Geological description
- 2-Geological profile
- 3-Wethering
- 4- Rock name

Physical and Geotechnical Properties

Start drill from 1m to 17.87m rocks are Silt and Sand with variation in color with change in physical properties of the rock. The bottom of well at depth 17.85meter formation is Silt and is described as Dark grey in color, wet, soft and low plasticity. At depth 17.85meter to 35meter rock is Agglomerate (Basement).

Color: Reddish brown.

Grain: Coarse grained

Hardness: Massive

Support: Grain supported

Sorting: Poorly sorted

Granular: Composed welded angular to sub angular fragment mainly rhyolite.

Engineering Properties of Agglomerate

Weathering: Variation from Fresh to Slightly weathering

Strength: Range from very low to highly strength related to depth

RQD: 80%-100%

Fresh water return: 0%-20%

Joint Characteristics

Angle of dip: 45degree

Shape: Irregular

Roughness: Rough
 Coating: Calcite / Iron oxide
 Spacing: Close

Borehole 412		
Depth (m)	Lithology	Legend
0 – 10		 Sand with Silt  Agglomerate
10 – 20		
20 – 30		Angle of dip: 45degree
30 – 40		RQD: 80%-100%

Figure 4: Lithology of Borehole 412

Borehole Number (403)

This well is drill with total depth 61.10meter
 Is start by Sand is dominate rock with thin layer of Silt.

Sand Describe As

Color: variation in color
 Grain: Fine to Coarse grain
 Shape: Subrounded to angular
 Graded: Poorly grad
 Homogeneity: Homogenous rock
 Composition: Composed of sand and feldspar

Silt Describe As

In depth 16meter to 19meter rock is composed of minor Sand, minor Clay and trace Gravel
 Color: Dark grey
 Moisture: Wet
 Hardness: Soft
 Plasticity: Medium

Sand Describe As

At 19meter to 56.10meter
 Color: variation in color
 Grain: Fine to Coarse grain
 Shape: Subrounded to angular
 Graded: Poorly grad
 Homogeneity: Homogenous rock

Agglomerate Rock (Basement) at 56.10meter to 61.10 Meter Describe As

Color: Reddish brown.
 Grain: Coarse grained
 Hardness: Massive
 Support: Grain supported
 Texture: Heterolithic
 Sorting: Poorly sorted

Granular: Composed welded angular to sub angular fragment mainly rhyolite.

Engineering Properties of Agglomerate

Weathering: Slightly weathering along joint plane, spacing fracture 7mete along joint plane by drilling

Strength: Highly strength

RQD: 15%- 89%

Fresh Water Return %: 99%

Joint Characteristics

Angle of dip: 10-60 degree

Shape: Irregular

Roughness: Rough

Coating: Kaolinte / Calcite

Spacing: very wide i.e. more than 2meter

Borehole 403		
Depth (m)	Lithology	Legend
0 - 10		 Sand
10 - 20		 Silt
20 - 30		 Agglomerate
30 - 40		Angle of dip
40 -50		10° - 60°
50 - 60		QRD
60 - 70		15% - 89%

Figure 5: Lithology of Borehole 403

Borehole Number 149

Total depth 50.30meter

This well start by thin layer of silt with some sand, and silt.

Silt is Described As

Color: Dark grey

Moisture: Wet

Hardness: Soft

Plasticity: Low plasticity

Sand is Found in 2.70 Meter to 45.30 Meter and Describes As

Color: dark grey to grey in color
 Grain: Fine to Coarse grain with some silt
 Shape: Sub rounded to angular
 Graded: Poorly graded
 Homogeneity: Homogenous rock
 Composition: Quartz & Feldspar
 Grain shape: Subrounded to subangular

Agglomerate Rock (Basement) at 45.30meter to 50.30 Meter Describe As

Color: Reddish brown.
 Grain: Coarse grained
 Hardness: Massive
 Support: Grain supported
 Texture: Heterolithic texture
 Sorting: Poorly sorted
 Granular: Welded angular to sub angular fragment mainly rhyolite and part of ignimbrite.

Engineering Properties of Agglomerate

Weathering: Slightly weathering along joint plane
 Strength: Highly strength
 RQD: 46%- 100%
 Fresh water return: 95% - 99%

Joint Characteristics

Angle of dip: 0.0-10 degree
 Shape: Irregular
 Roughness: Rough
 Coating: Kaolinite / Calcite and Iron oxide
 Spacing: very wide i.e. more than 2meter

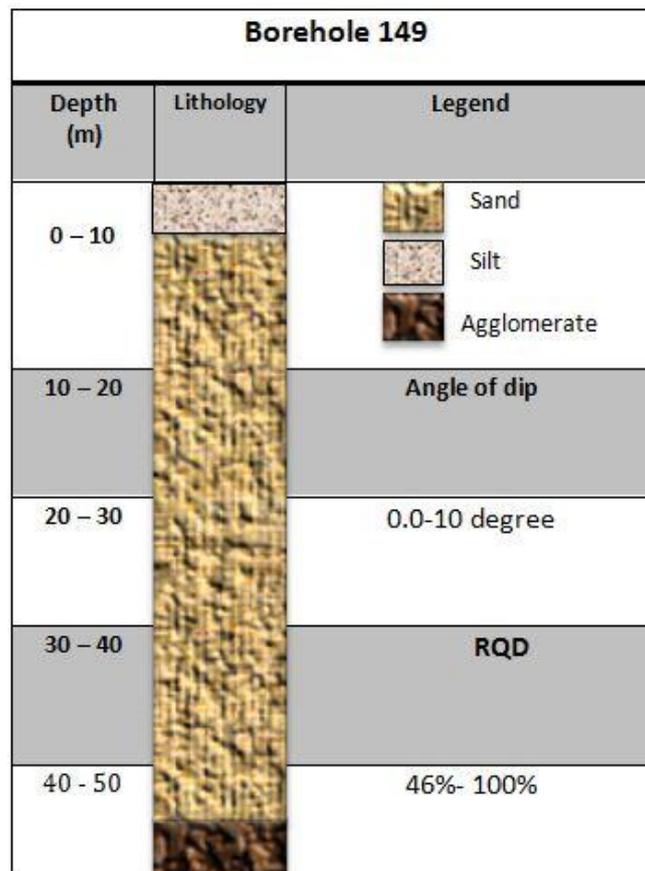


Figure 6: Lithology of Borehole 149

Summery of Drilling Result

The drill borehole at study area than can identification of geological characteristic and engineering properties of ground by knowing of the structures and stability with types of joint characteristics that summarized in table 4.9 show the orientation, material filling, degree or spacing and all of this information can help to identification the characteristic of the basements and which stable area for build project, subsurface layers various into sand and silt formation with basement rock type is Agglomerate. The selection of three borehole is based on the location of dam and it surveyed the area of project with given full information at that we observation the ground of the three borehole is typically matched but there are some different into the thickness of layer such as Agglomerate in the borehole number 412 is more than other and it found at shallow while in the other borehole is found deep in the bottom it with thickness 5meter and in 412 is 50% of total depth is Agglomerate and sediment formation in top Sand and Silt formation at drilling we test the strength of rock during drilling and used SPT test with permeability and joint characteristic to measurement the engineering properties of rock and that is give good evidence of the study area with full data concerned to project, the drilling borehole by rotary rig with geotechnical engineering method and test.

	Spill way left channel	Island	Cofferdam spill way
Borehole number	403	412	149
Total depth	61.10meter	35.00meter	50.30meter
Rock types	sand / silt agglomerate	sand / silt agglomerate	sand / silt agglomerate
Agglomerate depth	56.10 meter	17.85 meter	45.50 meters
Rock Quality Designation (RQD)	15% - 89%	80% - 100%	46% - 100%
Basement Weathering	fresh to slightly	fresh to slightly	fresh to slightly
Joint Characteristics			
Angle of dip	10° - 60°	0.0° - 45°	0.0° - 10°
Shape	Irregular	irregular	irregular
Roughness	Rough	rough	rough
Coating	kaolinite / calcite / iron oxide	calcite / iron oxide	calcite / iron oxide
Spacing	very wide	close	very wide

Table 2: Correlations Between Boreholes no. 403, 412 &149

Conclusion And Recommendations

The study was conducted to examine the suitability of the selected site for the proposed hydro-power dam that located on the River Nile at about 80 km north of Khartoum town. The site is located at the narrow gorge of the River Nile on the volcanic plateau that mainly occupied by acid volcanic rocks characterized by highly jointed rocks. The main fractures trends are in NW and NE that need to be considered during the dam implementation. The dam axis is located on the relatively less fractured Agglomeratic rocks, three boreholes is typically matched but there are some different into the Depth of Basement (Agglomerate) This study has recommended that This research work suggested that during construction phase the engineering geologist should take worry of horizontal lithological variation by taking photos and mapping the foundation geology [5-7].

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