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"Building Materials Engineering Characterization for Proposal Sabaloka Dam"

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Abstract:

The proposed dam is located at the Sabaloka igneous complex on the sixth cataract of the Nile, where the Nile passes through the volcanic plateau of Sabaloka. At the proposed dam site, the exposed rocks are Agglomerate, Rhyolite and Ignimbrite.

The storage capacity of the proposed dam is about 4000 million cubic metres, and its lake extends south to about 15 km and the water level is expected to rise from 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 habitant for fisheries in the lake behind the dam.

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. In this study, the geotechnical characteristics of rock samples from the area near the proposed site for the construction of the dam were tested. And through this study, these rocks were Suleik Granite, Trachy Basalt and Prophyirtic Microgranite, identified that can be used in the construction of the dam due to their suitable engineering properties

In order to obtain numerical scientific values, which assisting in acquiring good quantitative and qualitative evaluation, many tests (8 samples) have been carried out based on international standard methods table (5.1), as British standard (BS), American standard for testing Material (ASTM) and the American association of state High and transportation officials system (AASHTO) Rock samples are tested at the laboratory of building and road research institute (BRRI, University of Khartoum). Geological research Authority of Sudan (GRAS, Khartoum) and Road and Bridges Public Corporation (RBPC, Khartoum).

Key words: Suleik Granite, Trachy Basalt, Prophyirtic Microgranite, River Nile, Sabaloka dam, Sudan.

1. INTRODUTION

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 habitant for fisheries in the lake behind the dam.

The main objective of this study is to identify the engineering properties of rocks from Sabaluka through laboratory tests

2- 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 exposures in Sudan, attracted the interest of may geologists such as; Delany (1958), Kroner et al (1987), Dawoud & Sadig (1988) and Almond & Ahmed (1993) to study different geological aspects of this area

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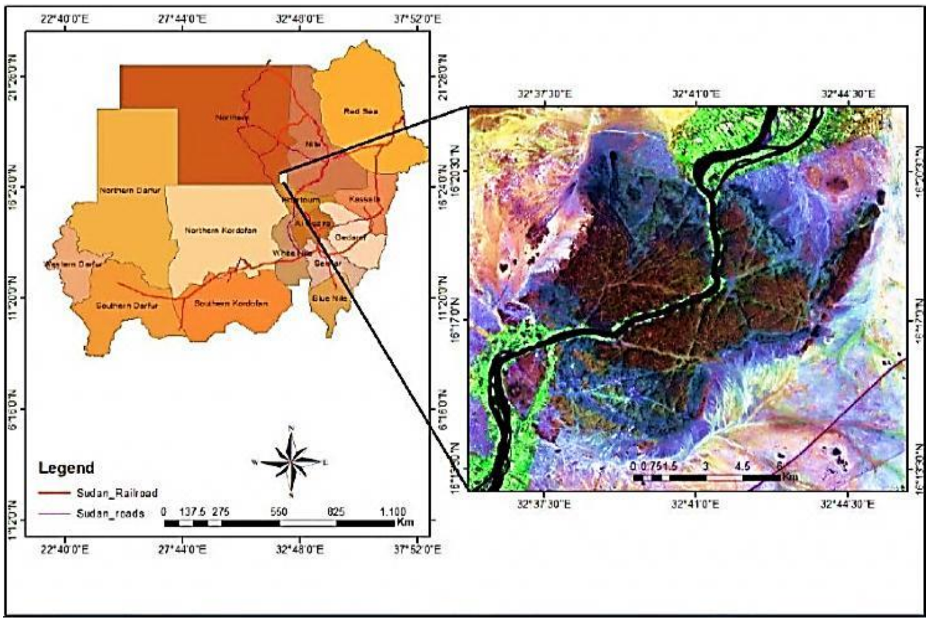

Figure 1 The Study Area

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). 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).

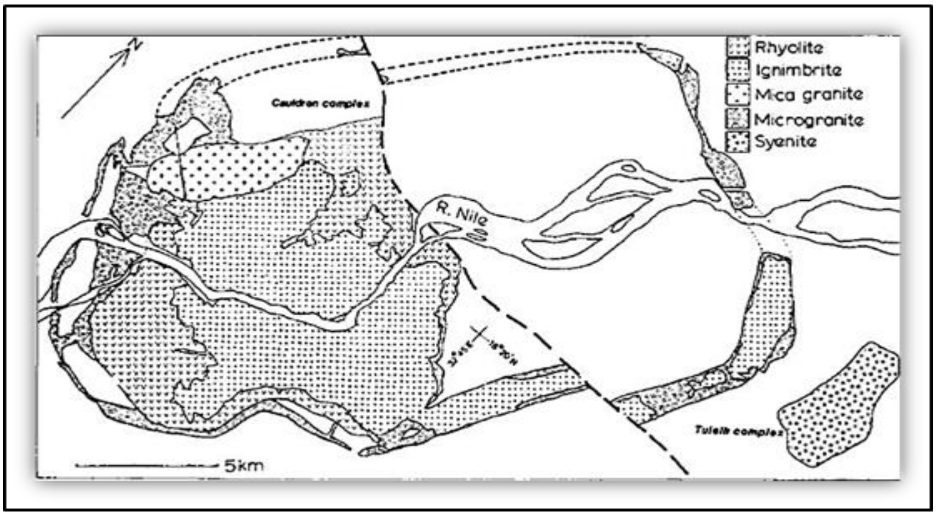

Figure 2 Geological sketch map of Sabaloka igneous complex by (N. B. W. Harris, H. J. Duyverman & D. C. Almond 1993)

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1. **Rock Geotechnical Tests**

In order to obtain numerical scientific values, which assisting in acquiring good quantitative and qualitative evaluation, many tests (8 samples) have been carried out based on international standard methods table (5.1), as British standard (BS), American standard for testing Material (ASTM) and the American association of state High and transportation officials system (AASHTO) Rock samples are tested at the laboratory of building and road research institute (BRRI, University of Khartoum). Geological research Authority of Sudan (GRAS, Khartoum) and Road And Bridges Public Corporation (RBPC, Khartoum).

3.1 Specific gravity and Water Absorption Test

Specific gravity and Water Absorption Test of Aggregates are major important tests to be performed on aggregate. These two parameters or properties of aggregate play an important role in the mix design of concrete. As we know that aggregate occupies 70 to 80% volume of concrete, its testing becomes essential before use.

"Specific Gravity is defined as the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water."

The specific gravity is usually showed the strength and quality of the material**.** The specific gravity of aggregates test is usually used to the identification of stones or aggregates.

Aggregates with low specific gravity value are mostly weaker than those with higher specific gravity values.

Water absorption of aggregates is the % of water absorbed by an air-dried aggregate when immersed in water at 27°C for a period of 24 hours.

Water Absorption of Aggregate **(WA%)** = % by weight of water absorbed in terms of oven-dried weight of aggregate

WA = A – B / A 100%

Where:

A: weight of dry sample in air.

B: weight of saturated sample in air.

Specific gravity and water absorption of a coarse aggregate lab report is prepared after calculating above values.

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Figure 3 Specific gravity and water absorption are measuring instruments in the laboratory

Table 1 Water Absorption

Sample No	Rock Type	WA%
1	Light Ignimbrite	0.48
2	Dark Ignimbrite	0.16
3	Upper Rhyolite	0.75
4	Trachy Basalt	0.35
5	Lower Rhyolite	0.48
6	Suleik Granite	0.20
7	Babados Granite	0.15
8	Prophyirtic Microgranite	2.63

3.2 Aggregate impact value (AIV) Test

AIV test is conducted to determine the Aggregate Impact Value of Coarse aggregate. The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from Its resistance to a slow compression load.

The ratio of the Weight of fraction passing through 2.36-mm IS Sieve to total weight of oven-dried sample.

AIV = W2/W1*100

Where: W1: Weight of Aggregate Sample Filling in Cylinder (gm)

W2: Weight of Aggregate Passing the 2.36 mm Sieve after test (gm)

Figure 4 Aggregate Impact Value Testing Machine

Table 2 Aggregate impact value (AIV) %

Sample No	Rock Type	(AIV) %
1	Light Ignimbrite	9.11
2	Dark Ignimbrite	7.52
3	Upper Rhyolite	3.72
4	Trachy Basalt	3.80
5	Lower Rhyolite	3.72
6	Suleik Granite	9.78
7	Babados Granite	8.66
8	Prophyirtic Microgranite	8.00

3.3 Aggregate crushing value (ACV) Test

It is the ability of aggregates that resist sudden impact or shock load on it. Also, it can be defined as the resistance of aggregate to failure by impact load is known as the Impact Value of Aggregate.

Table 3 Aggregate Crushing Value (ACV) %

Sample No	Rock Type	(ACV) %
1	Light Ignimbrite	19.50
2	Dark Ignimbrite	14.80
3	Upper Rhyolite	17.60
4	Trachy Basalt	13.77
5	Lower Rhyolite	19.46
6	Suleik Granite	27.56
7	Babados Granite	44.39
8	Prophyirtic Microgranite	23.65

3.4 Soundness Test

Soundness is the percentage loss of material from an aggregate blend during the sodium or magnesium sulfate soundness test. This test, which is specified in ASTM C88 and AASHTO T104, estimates the resistance of aggregate to in-service weathering. It can be performed on both coarse and fine aggregate. The test is performed by exposing an aggregate sample to repeated immersions in saturated solutions of sodium or magnesium sulfate followed by oven drying. One immersion and drying is considered one soundness cycle. During the drying phase, slats precipitate in the permeable void space of the aggregate. Upon reimmersion, slat rehydrates and exerts internal expansive forces that simulate the expansive forces of freezing water.

The rest result is total percentage loss over various sieve intervals for a required number of cycles. Maximum loss values typically range from 10% to 20% for five cycles.

When referring to table (5.5) all the rock type exceeded the soundness test and they are suitable as concrete aggregate material, but when taking table (5.1) in consideration most of them are not suitable except trachy basalt and Suleik granite

Table 4 Soundness Value (SV) %

Sample No	Rock Type	(SV) %
1	Light Ignimbrite	9.00
2	Dark Ignimbrite	5.80
3	Upper Rhyolite	7.40
4	Trachy Basalt	6.70
5	Lower Rhyolite	7.40
6	Suleik Granite	6.00
7	Babados Granite	8.80
8	Prophyirtic Microgranite	6.95

3.5 Density Test

The unit weight is determined by the formula below. Subtract the weight of the measuring base from the combined weight of the measuring base and the concrete it contains. Next, divide this weight (in pounds) by the volume of the measuring base (cubic feet) to obtain the density expressed as lb/ft3:

$$D = (Mc - Mm) / Vm$$

D = Density of the concrete, lb/ft3

Mc = Weight of the measure holding the concrete

Mm = Weight of the empty concrete measure (base of air meter)

Vm = Volume of the measure (usually about 0.25 ft3 for a pressure meter base)

Table 5 Density g/cm3

Sample No	Rock Type	Density g/cm3
1	Light Ignimbrite	2.53
2	Dark Ignimbrite	2.61
3	Upper Rhyolite	2.53
4	Trachy Basalt	2.75
5	Lower Rhyolite	2.53
6	Suleik Granite	2.77
7	Babados Granite	2.59
8	Prophyirtic Microgranite	2.59

3.6 Point Load Test

The Point load test is an index test by which the rock is classified according to the strength. The test can be used to estimate other characteristics of intact rocks with which it correlates, such as uniaxial compressive and tensile strength. The test determines the strength index values at a point (Is (50)) and the anisotropy index (Ia (50)). The anisotropy index represents the strength ratio at point load in the directions with the lowest and highest values of the strength index.

The test device consists of the sample load and force gauges, and sample dimensions (length scale) is also measured during the test.

Point load strength index (I_s) = $(P*1000)/D^2$ Mpa

Where: **P** is breaking load in kN

D is the distance between platens in mm

Corresponding point load strength index for the standard core size of 50 mm (I_{s50}) diameter is given by the following equation

$I_{s50} = (P*1000)/(D^{1.5}\sqrt{50})$ MPa

Figure 6 Point Load Testing Machine

Table 6 Point Load Test

Sample No	Rock Type	Point Load Test (PL) KN/M^2
1	Light Ignimbrite	12.52
2	Dark Ignimbrite	-
3	Upper Rhyolite	11.58
4	Trachy Basalt	8.14
5	Lower Rhyolite	8.61
6	Suleik Granite	2.74

7	Babados Granite	10.48
8	Prophyirtic Microgranite	7.82

.37 Los Anglos Abrasion (LLA)

The Los Angeles (L.A.) Abrasion Test is widely used as an indicator of the relative quality of aggregates. It measures the degradation of standard gradings of aggregates when subjected to abrasion and impact in a rotating steel drum with an abrasive charge of steel balls.

The drum is fitted with an internal shelf that lifts and drops the charge and sample with each revolution, generating impact forces. After the machine has completed the required rpm, contents are removed and percent loss is measured

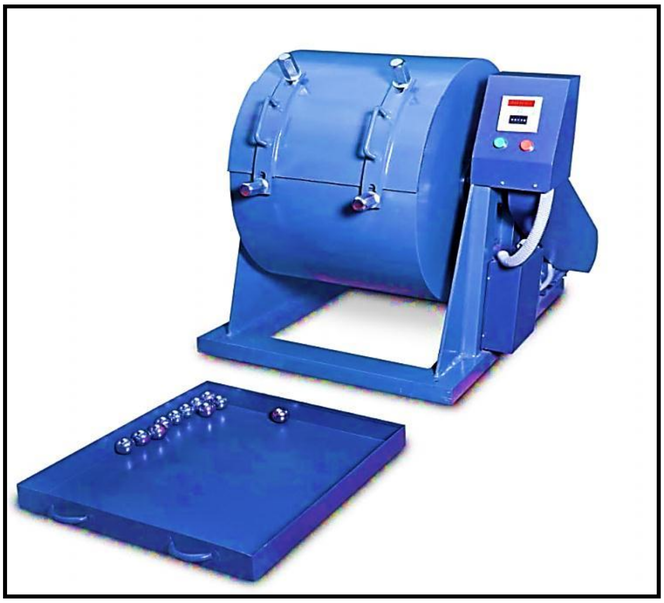

Figure 7 Los Anglos test machine

Table 7 Los Anglos Abrasion (LLA)

Sample No	**Rock Type**	**LLA%**
1	Light Ignimbrite	19.50
2	Dark Ignimbrite	19.45
3	Upper Rhyolite	19.16
4	Trachy Basalt	12.50
5	Lower Rhyolite	15.32
6	Suleik Granite	27.56
7	Babados Granite	44.38
8	Prophyirtic Microgranite	23.34

3.8 Uniaxial Compressive Strength Test (UCS)

A measure of a material's strength. The uniaxial compressive strength (UCS) is the maximum axial compressive stress that a right-cylindrical sample of material can withstand before failing. It is also known as the unconfined compressive strength of a material because confining stress is set to zero.

The procedure of this test is as follows:

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a) Cut the samples to cubes, length of each polygon is 50mm.
b) Put the specimen under vertical pressure effect, the result from two cylindrical shape metallic plates that the specimen put between them.
c) Record the applied power at the moment of the rock specimen starts collapsing and divide by the specimen section to get the uniaxial compressive strength, as the following:

UCS = P_{max} N

Where:

V=D= length of cube polygon that equal 50mm

The results of this test for all rock samples are shown in (Table)

Table 8 Uniaxial Compressive Strength Test (UCS)

Sample No	Rock Type	Density g/cm^3
1	Light Ignimbrite	-
2	Dark Ignimbrite	7.52
3	Upper Rhyolite	40.4
4	Trachy Basalt	-
5	Lower Rhyolite	7.2
6	Suleik Granite	15.35
7	Babados Granite	12.2
8	Prophyirtic Microgranite	44.3

3.9 The Results of Geotechnical Test In The Rock Sample

The low value of (AVI), (LAA) and (ACV) means higher resistance to the impact, abrasion and crushing, reverse the maximum value witch mean less quality.

In general, these rocks have shown high durability in geotechnical tests and the size and shape of the cuts which may positively or negatively affect the purpose for which the study was conducted.

Table 9 Results of Geotechnical Test In The Rock Sample

Rock Name	AIV%	LAA%	ACV%	Specific gravity	WA%	SV%	PL KN/M^2	UCS
Light Ignimbrite	9.11	19.50	19.50	2.53	0.48	9.00	12.52	-
Dark Ignimbrite	7.52	19.45	14.80	2.58	0.16	5.80	-	7.52
Upper Rhyolite	3.72	19.16	17.60	2.49	0.75	7.40	11.58	40.4
Trachy Basalt	3.80	12.50	13.77	2.70	0.35	6.70	8.14	-
Lower Rhyolite	3.72	15.32	19.46	2.49	0.48	7.40	8.61	7.2
Suleik Granite	9.78	27.56	27.56	**2.77**	0.20	6.00	2.74	15.35
Babados Granite	8.66	44.38	44.39	2.57	0.15	8.80	10.48	12.2
Prophyirtic Microgranite	8.00	23.34	23.65	2.66	-	6.95	7.82	44.3

2. Conclusion And Recommendations

There are different types of rocks in the area, and through the tests that were carried out in this study, it became clear that two of them can be used in construction, which are Suleik Granite, Trachy Basalt and It can also be used Prophyirtic Microgranite

I recommend making a geotechnical map of the Sabaloka region to facilitate access and benefit from the materials in there.

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الملخص:

يقع السد المقترح في مجمع سابالوكا الناري على الشلال السادس لنهر النيل في جمهورية السودان ، حيث يمر النيل عبر هضبة سابالوكا البركانية. في موقع السد المقترح ، الصخور المكشوفة هي Agglomerate و Rhyolite و Ignimbrite.

وتبلغ الطاقة التخزينية للسد المقترح حوالي 4000 مليون متر مكعب ، وتمتد بحيرته جنوباً إلى حوالي 15 كم ومن المتوقع أن يرتفع منسوب المياه من 6 إلى 10 أمتار.

تم اقتراح سد السبلوقة لأغراض متعددة ، خاصة لتوليد الطاقة المائية والري بالإضافة إلى المساعدة في تقليل ترسب الطمي في سد مروي في الشمال. علاوة على ذلك ، سوف يمثل موطنًا ممتازًا لمصايد الأسماك في البحيرة خلف السد.

أجريت هذه الدراسة للتحقق من الموقع المختار لسد الطاقة الكهرومائية المقترح. في هذه الدراسة تم اختبار الخصائص الجيوتقنية لعينات الصخور من المنطقة القريبة من الموقع المقترح لبناء السد.

من أجل الحصول على القيم العلمية العددية ،والتي تساعد في الحصول على تقييم كمي ونوعي جيد ، تم إجراء العديد من الاختبارات (8 عينات) بناءً على الأساليب القياسية الدولية مثل المعيار البريطاني (BS) والمعيار الأمريكي لاختبار المواد (ASTM) و يتم اختبار عينات الصخور في مختبر معهد أبحاث البناء والطرق (BRRI ، جامعة الخرطوم). هيئة البحوث الجيولوجية السودانية (GRAS ، الخرطوم) والمؤسسة العامة للطرق والجسور (RBPC ، الخرطوم).

حيث كما أثبتت الاختبارات الجيوتقنية على صخور المنطقة كفاءة حجر البازلت الجرانيت والسليك الموجود في منطقة سابالوكا لاستخدامهما كركام خرساني في البناء حسب المواصفات القياسية.