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Purposeful scientific research as a pillar of sustainable development

Geotechnical Logging of Exposed Rock Masses of Khans Area in Dohuk Governorate, Northern Iraq.

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ABSTRACT

The current study depends on geotechnical logging, represented by field and laboratory logging to evaluate the rock masses which consist from limestone rocks belonged for Pilaspi Formation at the Khans Dam site in northern Iraq. Field logging depened on discontinuities and intact rock in the rock masses, using the rock mass rating according to Bieniawski (1989). The values ranged between (49-59) ,these rock masses are considered Fair. As for the Rock quality designation based on the discontinuities and the distances between these discontinuities, their values ranged between (71.17-92.681%), meaning between (moderate to very strong). As for the geological strength index of the rocks, its values ranged between (54-64) which rock masses are located between (Fair to good). according to the plan adopted by (Sonmez & Ulusay, 2002 and Modified Hamasur, 2009). As for the laboratory test, it represented the results of the unconfined uniaxial compressive strength of these rocks on two banks, as it is located between (7.87MPa-20.64 MPa). As for the results of tensile strength using the indirect method (Brazilian method) and according to the classification (Deere & Miller, 1968), their values ranged between (2.10MPa - 2.62 MPa), it is considered medium. As for the petrophysical properties, they were represented by the dry density in gm/cm3, and their results ranged between (2.01-2.37)gm/cm3, while the water content values ranged between (0.178%-0.961%). As for the true specific gravity of these rocks in all stations, their values ranged between (2.55-2.62), while the total porosity values ranged between (6.30% -21.99%), and the absorption ratio results, their values ranged between (2.56%-10.91%). As for the test of the Petrographic properties of the thin section rock under microscope, it was found that they consist of limestone and dolomitic with diagenetic process and dissolution and cementation.

Keywords: Geotechnical logging 1; RMR 2; GSI 3 ; Petrophysics; 4 ; Khanas Dam5

1. Introduction

The geotechnical logging of the exposed rock masses at the Khans Dam site in northern Iraq is of most importance and essential for future predictions regarding these rock masses located on the slopes overlooking the banks of the Khans Dam reservoir. Site logging of rock masses is the process of evaluating the quality and properties of rock masses at a specific location, in order to understand their behavior and conduct under different loads, especially in the context of engineering projects. This loggging includes

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several aspects, including determining the type of rock, its degree of cohesion, texture, and rock components, determining its physical and mechanical properties, and evaluating the structural features represented by discontinuities (joints, and fissures present in these rock masses, in addition to evaluating their degree of resistance to weathering and erosion and assessing their degree of stability. This investigation is of great importance in engineering applications, including the stability of rock masses of slopes, foundation design and drilling planning. This research include two logging: field logging, which is represented by surface exploration, identifying discontinuities and their characteristics, and evaluating the quality of the rock, in addition to evaluating rock masses rating according to (Bieniawski, 1989). In addition to the laboratory logging, which is represented by finding the uniaxial compressive strength and tensile strength using the indirect method, using the Brazilian method, in addition to studying the petrophysical properties represented by the dry density, the true specific gravity, the porosity, and the absorption ratio, according to the standard specifications for each case, In addition to studying the petrographic properties of the rock masses, their components, texture type, and accompanying features according to the classification (Folk, 1962).

2. Location of the Study Area

The study area is located approximately 56 km northeast of Mosul city, specifically in the Sheikhan district. It is located within the southeastern part of the Sheikhan fold, specifically in the Khans area near the Assyrian ruins, and on both banks of the Khans Dam reservoir. It is limited by coordinates between latitude (36° 45' 22"N)(36° 46' 53"N) north and longitude (43° 25' 37"E)(43° 24' 05"E). Figure (1) show the location of the study area.

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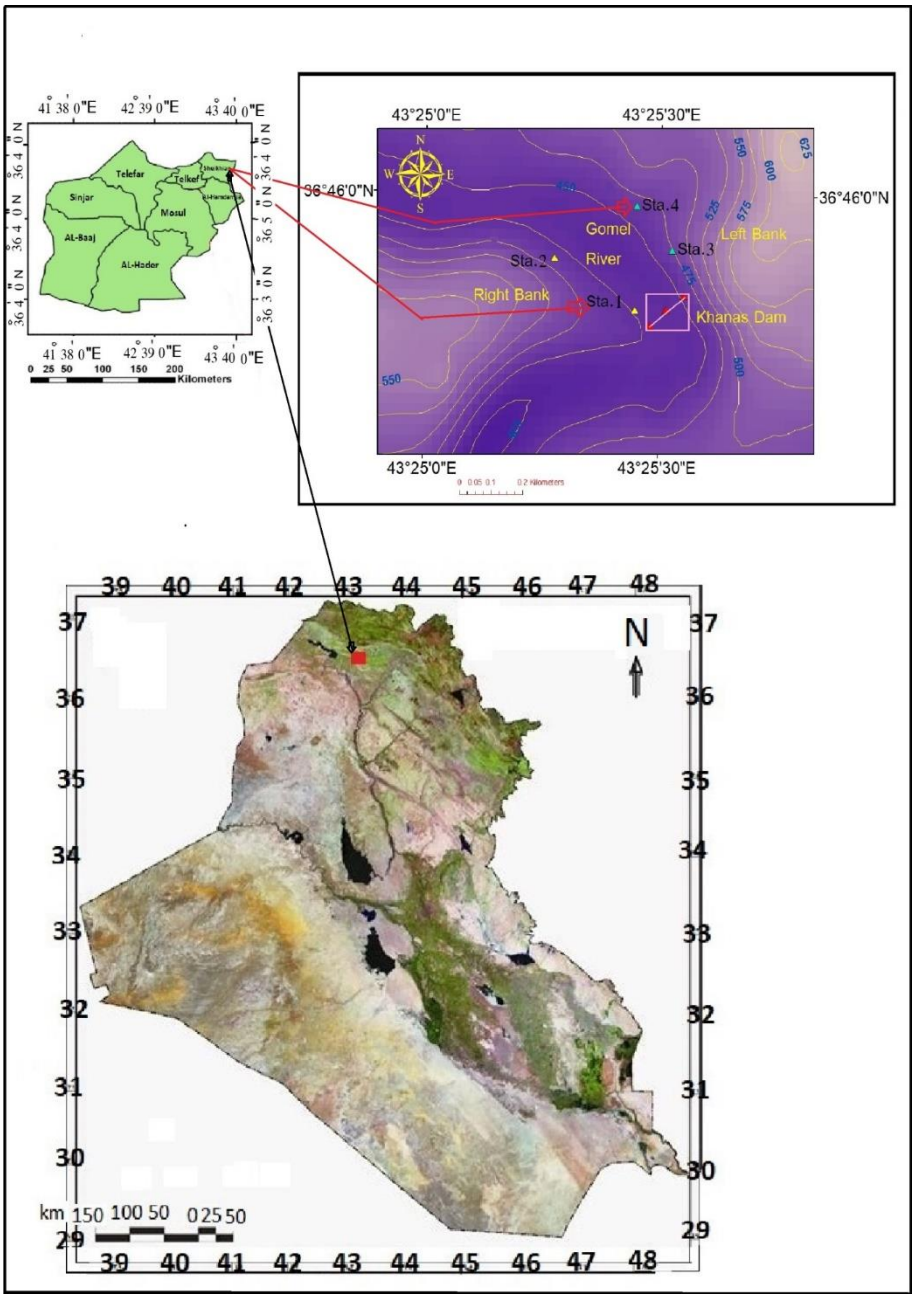


Figure 1. Location map of Study Area

3. Geology of the Study Area

The geological factor is an important factor influencing the location of the rock masses located on the banks of the reservoir, as the location of the study area is considered to be geologically complex, specifically on the southeastern limb of the fold. Whereas the rock masses are located on both banks of the reservoir and the river flow is perpendicular to the axis of the fold in the northwestern limb, then it deviates in its stream. Until it becomes parallel to the axis of the fold in the southeastern limb at the site of the dam and towards the downstream.

3.1 Tectonic and Structural of the Study Area

The study area is located within the unstable continental shelf and within the foothills, as described in the geology of Iraq by (Jassim & Goff, 2006) and according to (Fouad, 2012). It is located within the range of (Butmah - Chemchmal) and within the extension of the Taurus Mountains (east - west) with a deviation in

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the axis (east - northeast) (west – southwest) according to (Al-Khatony 2009) and (Al-Hubaity 2024) Al-Khatony, in the same source, prepared a geological and structural map of the Sheikhan fold, showing the study area, Figure (2). The dip value of the bedding plane on both banks ranges between(20 - 26) degrees with a large difference in the direction of the bedding planes, as shown in the plate (1).

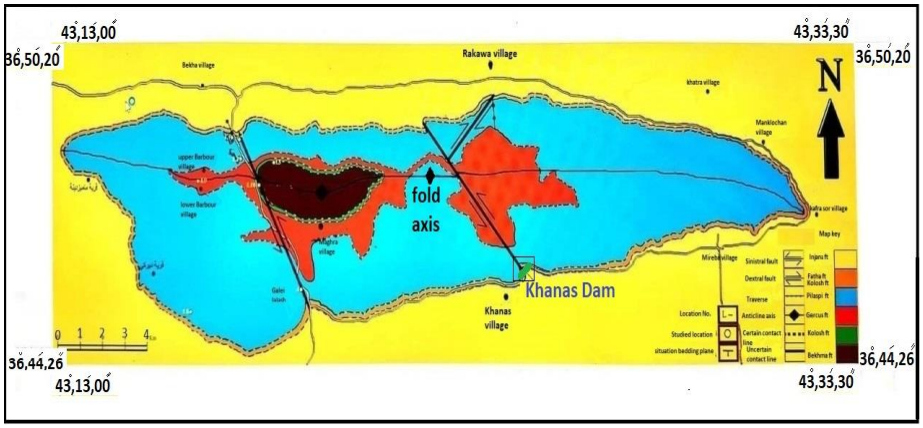


Figure 2. Structural and geological map of the Sheikhan anticline (Al-Khatony, 2009)

3.2 Stratigraphy of the Study Area

The study area reveals red clay deposits, characterized by the presence of small pieces of gypsum rock, along with gravel and sand. These sediments return to the Gercus Formation and their age represents the Middle Eocene, which represents the oldest exposed formation in the study area with the presence of recent sediment deposits that are present in the river stream, as the sediments of the Gercus represent the lake reservoir and banks, Then it is topped by younger rock masses, which represent limestone belonging to the Pilaspi Formation and is of (Middle - Late) Eocene age (Ahmed,1980,Al-Hemdy,2007).Which represents the core of the subject on which our current study in geotechnical logging depends.

4. Previous Study

(Zhang et al., 2018) studied the quantitative evaluations and comparisons between rock mass classification and geological strength index in tunnels and the use of rock mass classification parameter by collecting field information from tunnels. (Yousif, 2021) studied field and laboratory geotechnical investigations, including rock quality index and geological strength index and A laboratory test is the unconfined uniaxial compressive strength., in evaluating the Excavatability of Eocene limestone rocks around the Salman Depression, southern Iraq. (Al-Gart, 2023), studied field and laboratory investigations in evaluating rock masses RMR classification (Bieniawski, 1976, 1989), determining rock quality, and determining the geological strength index in evaluating the foundations of Makhol Dam, north of Salah al-Din Governorate. (Ghazi et al, 2023), studied rock mass classification techniques and their parameters as a perspective using field probe parameters represented by RMR, GSI, RQD, SMR in determining and evaluating the stability of rock slopes for weak rock conditions. (Noori et al., 2023), studied geophysical and geotechnical investigations to estimate the properties of rock masses in assessing the slope stability of rock masses. (Mohammed et al.,2023) studied the evaluation of rock masses for dam foundations in the Kanarwe River basin in Sulaymaniyah Governorate as a case study. (Awad & Abood, 2024) studied field and laboratory geotechnical investigations in evaluating the foundation rocks of the proposed Al-Baghdadi Dam in Anbar Governorate, western Iraq.

5. Research Methodology

The current study methods depended on two tracks in Geotechnical logging. The first track was represented by field logging, through relying on structural geology to provide the largest amount of field information

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represented by describing the distinctive discontinuities of the rock masses, represented by the length of the discontinuity, the width of the discontinuity opening, the nature of the material filling the discontinuity, and the nature of the discontinuity surface and orientation of discontinuity. The nature of weathering on the surface of the discontinuity to which these rock masses are exposed through physical factors such as heat, humidity, dryness, rain and wind. Where the distance between discontinuities, which is considered important information in finding and rock quality designation and is also important and inter in rock mass rating according to (Bieniawski, 1989) and then finding the geological strength index of the rock. This is done by relying on the classification of the rock mass according to the following equation: $GSI=RMR_{89}-5$, which will be discussed later. This in itself is considered a field logging, while the laboratory logging is represented by relying on both the unconfined compressive strength, which will be entered as a factor in the classification of the rock mass. The tensile strength by the indirect method, the Brazilian method, will be discussed, and then the petrophysical properties will be found, represented by the dry density (g/cm3), moisture content, True specific gravity, Total porosity, and absorption ratio. Then, the petrographic characteristics are evaluated and these results are linked together, and then the results are finding and compared with each other in describing and characterizing the rock mass in the field and in the laboratory. The selected stations are shown in the Plate (2).

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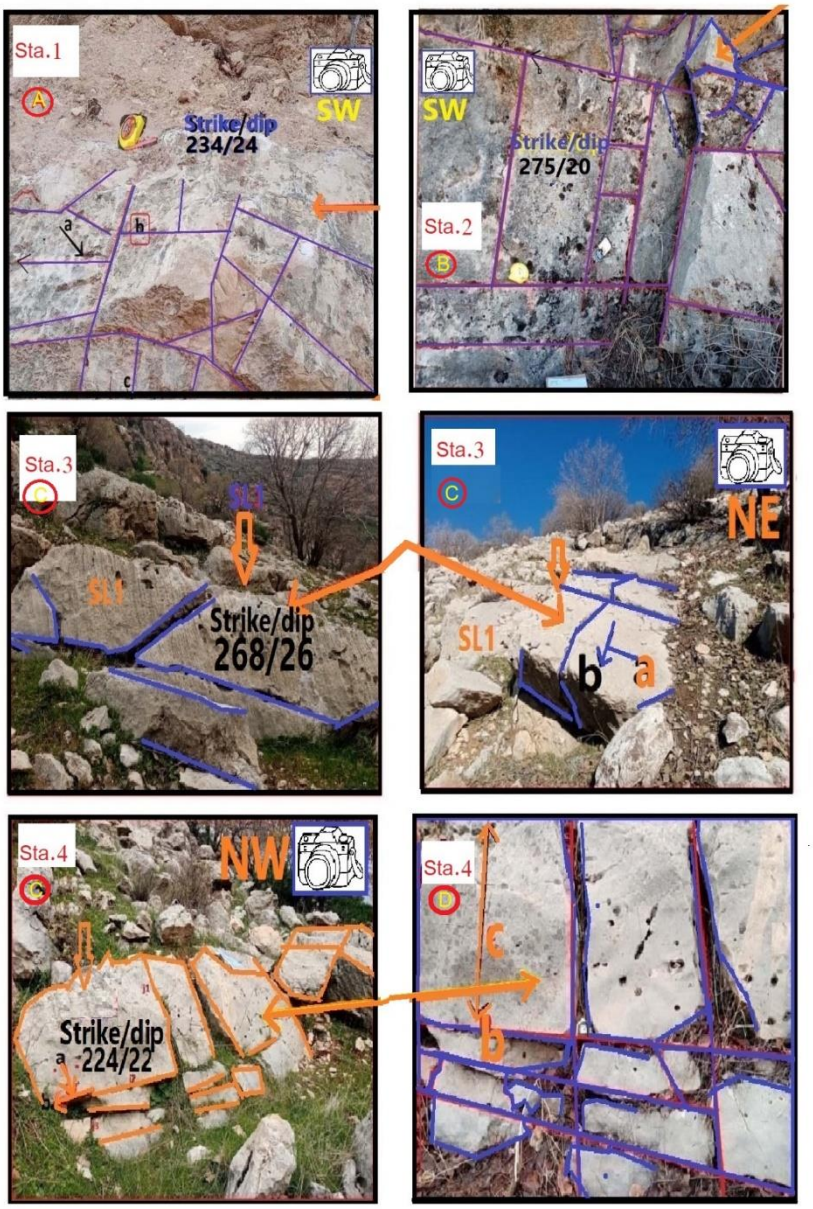


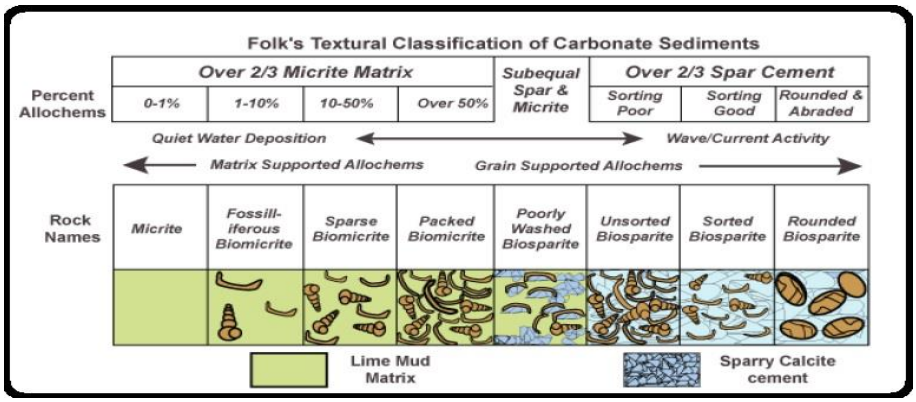
Plate 1. Pictures A: Represents the First station (Sta.1), B: Second Station (Sta.2) located on the right bank of the Khanas Dam. C: Third station (Sta.3), and D: fourth station (Sta.4) located on the left bank with shooting directions

6. Laboratory Logging

6.1 Petrographic Properties

Petrographic Properties of the rocks in the study area for the exposed rock masses on the right bank of the dam are represented by the first station (Sta.1), and second station (Sta.2), and rock masses exposed on the left bank are represented by the third station (Sta.3), and fourth station (Sta.4),. The rock masses were classified by relying on the classification (Folk, 1962) in naming the rock by relying on the percentage of grains, rock pieces, fossils, texture, and according to the Fig (4).

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Fiq 4. Carbonite rock classification according to (Folk, 1962)

1. As for the rocks of the first station (Sta.1) located on the right bank, through testing the rock thin section, it was found that they are (Dolomitic-limestone) facies, where the percentage of limestone is higher than dolomite, and it contains bivalve fossils, Pelspoide shells, in addition to containing red algae, and it is affected by diagenetic processes, which are mainly on them, then secondary cementation in the dissolution surfaces and in the fossil spaces, so the name of the rock is (Sparse Biomicrite)(Plate 2 A).
2. The second station (Sta.2) in the right bank: By testing the rock thin section, it was found that the percentage of limestone is higher than dolomite, so the name of the rock is micrite based on the classification (Folk, 1962). This facies is characterized by containing large voids and high porosity, and it is assumed that its specific weight is lower. The diagenetic processes affecting it are dolomitization and dissolution processes, in addition to the presence of iron oxides, (Plate 2 B).
3. As for the third station located on the left bank (Sta.3), the name of the rock is (Sparse -Biomicrite) and according to the classification of (Folk, 1962) it is affected by the dolomitization process and contains very high percentage of dissolution diagenetic processes (voids) and its general texture is described as an interlocking sieve texture (Sieve-Mosaic Texture) (plate 2 C)
4. The forth station (Sta.4) on the left bank : By testing the rock thin section under a microscope, it was found that the name of the rock is (Packed Biomicrite) and according to the classification (Folk, 1962) it contains high dissolution and cementation, high hardness and permeability, and evaporates, and is affected by the dolomitization process and contains dissolution voids and iron oxides, (plate 2 D).

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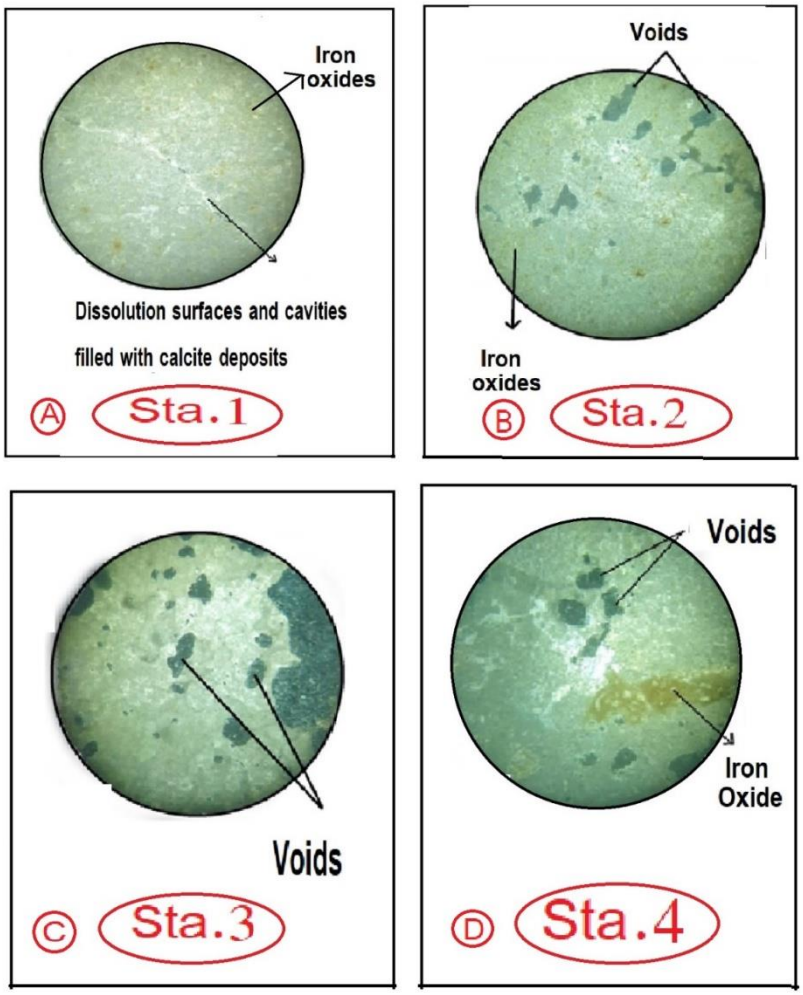


Plate 2. Show thin section for stations located on the right bank represented by A: Sat.1 and B: Sat.2 and located on the left banks represents by C: Sat.3 and D: Sat.4

6.2 Petrophysical Properties

Petrophysical properties are of great role for studying the engineering behavior of any rock material. Physical properties vary for several reasons, including differences in the type of cementing material, the strength of cohesion and compaction between grains, and the mineral content. The most important characteristic of a rock is its resistance to external forces imposed on it, as the relationship between forces and density is positive (Griffin, 2008). The petrophysical properties include all dry density, moisture content, absorption ratio, porosity, and true specific gravity, which will be found according to the American standard specification (ASTM-C-97-09, 2010) .

1- Dry density: It is defined as the mass per unit volume, where its unit is (g/cm3) or (kg/m3) (Ali et al,.1996) according to the Americaninternational specifications (ASTM-C-127-01, 2004). The more the depth increases, the more the density of the rocks increases. It depends largely on the texture of the material, porosity, the material filling the void, the mineral composition, and the amount of water in the pores and fractures (Polak & Raport, 1961).

$$Ɣdry = (\frac{Mdry}{Msat-Msub})Ɣw \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

result as shown table (1).

2- Moisture content: is the percentage of the mass of water present in the voids to its mass when dry (Ali et al., 1996). The water content is one of the main indicative properties of rock materials because of its strong

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relationship with the durability of the rock during both dissolution and freezing processes, and the elastic modulus, tensile and compressive strength (Zhang, 2005), which decreases with the increase in the water moisture content.

$$\text{Moisture content (mc)} = \frac{Mn-Md}{Md}*100 \quad \text{.....(2)}$$

result as shown table(1).

3- Water absorption: It is the ability of the rock to attract water between its pores and around the surfaces of the particles, so that the absorption of rocks depends mainly on several factors including (the shape, size and arrangement of the particles and the properties of the rock represented by compression, deformation and fractures.

$$W.ab = (Ww/Wd)*100 \text{ .....(3)}$$

result as shown table(1)..

4- Total porosity: Porosity is determined by a variety of chemical, physical, and geological processes, and varies widely across rock types, even within the same specimen. The most important factors affecting it are grain size distribution and grain shape, depth, and temperature (Lianyang & Zhang, 2017).

$$\eta = \frac{Msat-Md}{Msat-Msub}*100 \text{ .....(4)}$$

result as shown table(1).

5- True specific gravity: It is defined as the weight of the dry sample in air to the weight of the same volume of distilled water at a temperature of (20°C). It is considered one of the indicative properties of rocks. The following equation for calculating the specific gravity is as follows..

$$\text{True Specific gravity} = \frac{Md}{Md-Msub} \quad \text{.....(5)}$$

The result in table (1)

Table 1. show the result of the Petrophyics properties for rock mass located on the banks of the Khanas Dam reservoir in the southeastern part of Sheikhan Anticline

Stations	Dry density Gm/cm3	Moisture content %	True specific Gravity	Total porosity %	Water absorption %
Sta.1	2.18	0.749%	2.55	7.10%	2.99%
Sta.2	2.37	0.197%	2.55	6.30%	2.56%
Sta.3	2.20	0.178%	2.58	21.99%	10.91%
Sta.4	2.01	0.961%	2.62	10.70%	4.56%

6.3. Unconfined compressive strength

An indispensable factor in rock mass stability analysis for slopes, subsurface excavation, and support design for transportation, mining, and hydraulic projects. The compressive strength of a rock is defined as the vertical pressure exerted on the specimen at the point of failure. By determining the compressive strength, it is possible to determine the appropriate drilling technique. The applicable international American standard are (ASTM, C170M, 2016). The ratio of the length of the sample to the diameter to be tested is ($2 \geq \frac{L}{D} \geq \frac{1}{3}$) it is placed between two vertical metal plates, and the load must be (0.75 KPa/sec), provided that the failure of the sample occurs within (10) minutes. Since the thr diameter and length of the sample are known. The surface area of the sample is found using the following equation ($A = r^2 * \pi$). The force at failure is (KN) and the equation is ($\sigma c = F/A$) and then the compressive strength is corrected according to the following equation, which is as follows

$$\sigma cc = \frac{\sigma C}{0.778+0.222\frac{D}{L}} \text{ .....(6)}$$

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The results of compressive strength and its description according to (Geological Society) are as follows in Table (2):

Table 2. show the results of Uniaxial compressive strength at selected stations and description of Geolgical Society Engineering Group Work Partly,1978.

Right Banks	Sta.1	description	Sta.2	description
compressive strength	7.87425 MPa	Moderate weak	10.61023 MPa	Moderate weak
Left Banks	Sta.3	description	Sta.4	description
compressive strength	16.6656 MPa	Moderate strong	22.1267 MPa	Moderate strong

6.4 Tensile strength

It is obtained by uniaxial tensile testing, but tensile testing is difficult and expensive in routine applications. Rock mechanics engineers typically deal with tensile and compressive stresses. Under such conditions, tensile strength must be obtained with compressive stresses to be representative of field conditions. The test was carried out using the Brazilian method according to the specification. The samples are prepared in the form of a circular disc. The diameter to thickness ratio of the sample is (0.4) and according to the American specification (ASTM-D3967-08, 2016). The disc sample is placed vertically on the edges of a disc plate of a single-axis loading machine, with the loading speed being (0.05-0.35MPa) and the test takes (1-10) minutes until failure occurs. Tensile strength is used to determine and specify the extent of rock response to mechanical forces during blasting or drilling operations with various equipment. The equation used to find tensile strength is as follows

$$\sigma t = \frac{2F}{\pi dt} \quad \ldots\ldots\ldots\ldots(7)$$

The results are as follows, according to the classification of (Deere & Miller, 1966) table (3):

Table 3. Show the value of Tensile strength compressive and Description according of (Deere&Miller,1966).

Right Banks	Sta.1	Description	Sta.2	Description
Compressive strength tensile	MPa2.403557	moderate	MPa2.253334	moderate
Left Banks	Sta.3	Description	Sta.4	Description
Compressive strength tensile	MPa2.103112	moderate	MPa2.628890	moderate

7. Field Logging

7.1 Rock Quality Designation

Deere et al. (1976) came up with the idea of naming the rock quality classification to measure the quality of the rock using cores extracted for drilling at different lengths relative to the total length of the sample. Samples larger than 10 cm are taken an calculated, and those smaller than 10 cm are ignored. Due to the lack of rock core, we resorted to the second method, and through the rock exposure and the number of discontinuities present in the cubic meter volume unit. We relied on the distance between the discontinuities of the sets present in the rock exposure through the volume joints in the cubic meter unit, as the equation used to find the volume intervals is as follows:

$$J.V=1/S1+1/S2+1/Sn\ldots\ldots\ldots\ldots..Nr/5 \quad \ldots\ldots..(8)$$

The equation is used according to (Palmstrom, 2005) to calculate the rock quality designation. The results of the rock quality designation for the fourth stations, with a description of the quality and according to the type of rock mass, are shown equation by

$$RQD = 110 - 2.5\ (J.V) \quad \ldots\ldots(9).$$

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As the results with the general description of types of Rock mass are as follows:

Table 4. Result of the Rock Quality Designation for each station and located on the two banks

No.	Stations	Volumetric Joint (J.V)	Rock Quality Designation RQD=110-2.5(J.V)	Descriptions
1	Sta.1	9.066	87.33%	strong
2	Sta.2	8.4627	92.86%	strong
3	Sta.3	7.4628	91.34%	Very strong
4	Sta.4	15.530	71.17%	Moderate

7.2 Rock Mass Rating (RMR)

Originally, it is a geomechanical classification system. It was originally proposed by (Bieniawski, 1973) for use in tunnels, slopes, and foundations. It has undergone many developments over the years (1973, 1974, 1975, 1976, 1989),. The development of modified rock mass classifications from (Milne et al., 1998) modified the classification assigned to different parameters. It includes all of the following: uniaxial unconfined compressive strength, rock quality designation, distance between discontinuities, discontinuity conditions, groundwater conditions, and discontinuity orientation.. The six coefficients are combined as follows Rock Mass Rating Basic:

$$RMR_b = R1 + R2 + R3 + R4 + R5+R6 \quad \text{……..(10)}$$

The results are as follows for the rock masses on the right and left banks of the dam in table (5)

Table 5 . Assessment of the (RMR) system in first ,second, third and fourth stations.

Geological Unit	**Pilaspi Formation**			
Rock mass unit	Sta.1	Sta.2	Sta.3	Sta.4
Height (above sea level)	468m	492m	506m	483m
The thickness of unit (m)	0.60m	0.69m	0.50m	0.40m
Rock type	Limestone	Limestone	Chalky-limestone	Limestone
Attatiude of bedding plane Dip direction/dip amount	144/24	185/20	178/26	134/22
Strength of intact rock material USC(MPa)	10.61023 MPa	7.87425 MPa	8.2018 MPa	11.97158 MPa
RQD	87.3343%	92.680%	91.3428%	71.173%
The Average spacing of all discontinuities $= \frac{1}{Average\ j.v}$ According (Bieniawski,2011)	330.89mm	433.039mm	535.98mm	257.55mm

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Condition of Discontinuities	1-Length of Discontinuities =(0.60) m 2-Separation =(1mm) 3-Roughness rating = (rough) 4-Infilling soft filling (<5mm) 5-Weathering = (Slight)	1-Length of Discontinuities =(1.30)m 2-Separation(1mm) 3-Roughness rating = (very rough) 4-Infilling soft filling (<5mm) 5-Weathering =(Moderate)	1-Length of Discontinuities = (0.75) m 2-Separation (>5mm) 3-Roughness rating = (rough) 4-Infilling soft filling = (None) 5-Weathering = (Moderate)	1-Length of Discontinuities = (0.69) m 2- Separation (>5mm) 3-Roughness rating = (rough) 4-Infilling soft = (None) 5-Weathering = (Moderate)
Ground water condition	Flowing 0	Damp 10	Damp 10	Damp 10
Volumetric joint count (joint vm^3)	9.066279	6.92778	7.462857	15.530
Rating adjustment for disciontinuity orientation	Favourable -2	Favourable -2	Favourable -2	Favourable -2
RMR_{89}	49	59	59	53

7.3 Geologic Strength Index

The geologic strength index was introduced by Hoek (1994), Hoek & Brown (1997), and Hoek (1995) to overcome the shortcomings of Bieniawski rock mass classification for very poor-quality rock masses. The geologic strength index estimates the decrease in rock mass strength under various geologic conditions as determined through field observations. The determination of rock mass properties is based on the visual impression of the rock structure, in terms of the blackness and surface condition of discontinuities, which indicate the roughness of the discontinuity and alteration (Hoek, 1994). The calculation of the geological strength index was based on rock mass rating (Bieniawski, 1989), which is as follows:

$$GSI = RMR_{89}-5 \text{…….(11).}$$

The quantitative chart of (Sonmez & Ulusay, 2002) was relied upon, modified from (Hamasur, 2009), and this was based on the chart that depends on two axes. The y-axis represents the classification of the structure, and according to the equation it is as follows:

$$SR=100-17.5322\ ln\ (J.V)\text{……..(12)}$$

and the x-axis represents the extent of the discontinuity surface by combining the roughness, weathering, and infilling material classifications of the discontinuity, as follows:

$$SCR= Rf + Rw + Rr \text{ ……(13)}$$

The second method was adapted according to the table (6) and Figure (3)

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Table 6. Result of the Geological Strength Index by using method depending on the Quantitative evaluation for (Snomez&Ulusay,2002) and Modified by Hamasur,2009..

Area	Stations	Thickness	Joints Volumetric	SR	Rr	Rw	Rf	SCR= Rr+Rw+Rf	GSI From Chart
Right bank Pilaspi Formation	Sta.1	0.60m	9.10	61.34	4	4	1	9	46
	Sta.2	0.69m	6.92	66.06	5	2	1	8	61
Left bank Pilaspi Formation	Sta.3	0.50m	7.46	64.76	5	2	4	11	58
	Sta.4	0.40m	15.53	51.91	4	2	5	11	51

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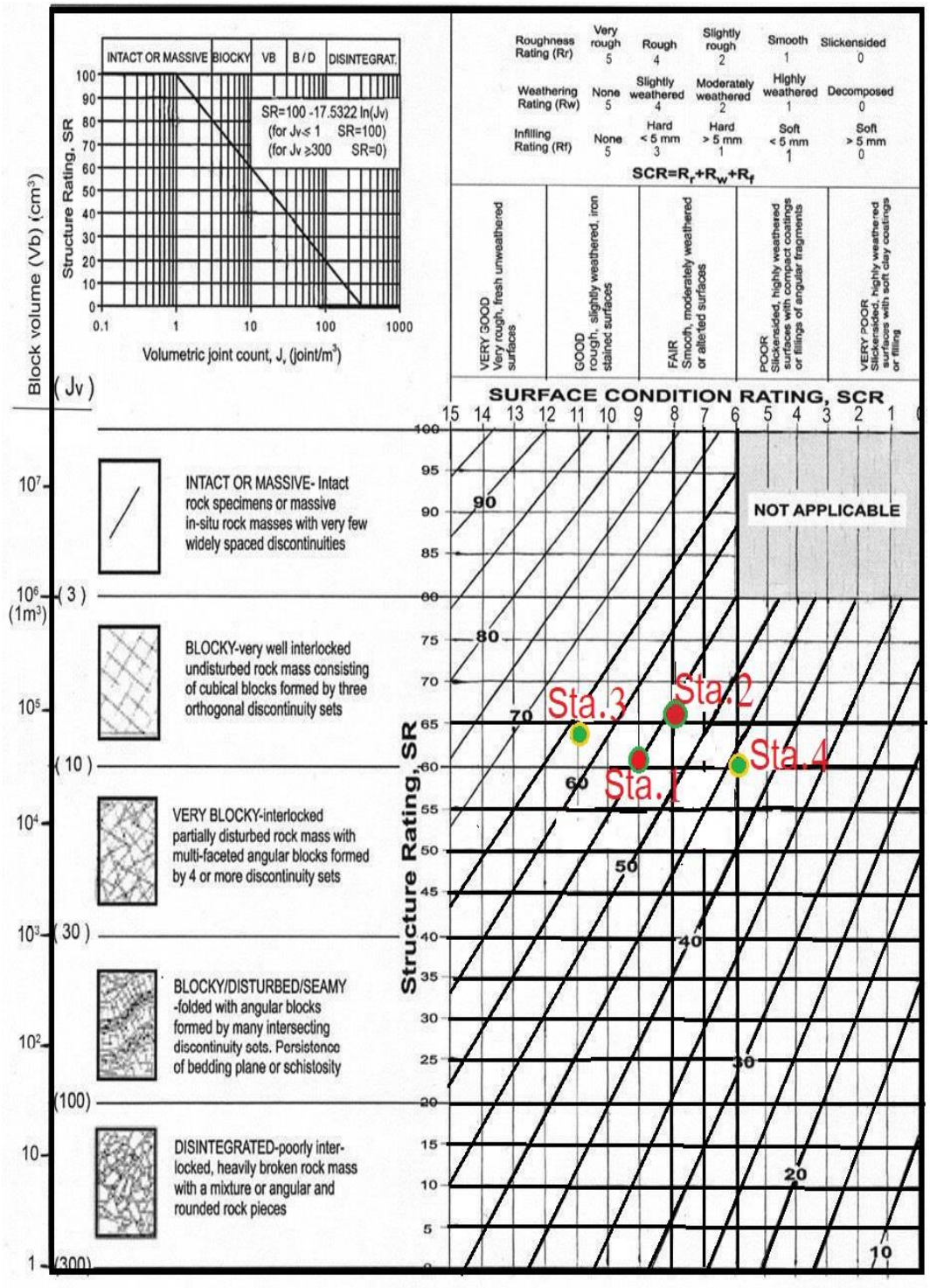


Fig 3. Quantitative Estimation of the Geological Strength Index of (Snomez&Ulusay,2002) and Modified from (Hamasur,2009).

8. Conclusion

1- The results of the field logging, represented by the evaluation of the the rock masses rating(RMR) according to the classification (Bieniawski, 1989), for the first station(Sta.1) second station(Sta.2) thrid station(Sta.3) and fourth station (Sta.4) the results showed that the rock masses of all stations were fair rock

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2- The results of the field logging in evaluating the results of the geological strength index also showed the second station and third station () were good quality .while the first station (Sta.1) and fourth station (Sta.4 which are rocks of fair quality.

3- The results of the rock quality designation (RQD) classification, based on the inter-discontinuity distances and their relationship to the rock quality, according to the volumetric joints (J.V) and according to the relationship RQD = 100-2.5(J.V) according to (Palmstrom, 2005), showed that the rock masses are rocks of strong quality in the first station(Sta.1) and second station (Sta.2), and very strong for third station (Sta.3), which the rock quality designation is Moderate in the fourth station (Sta.4).

4- Moisture Content: The moisture content appeared to be very low in the third station (Sta.3) This is due to the rock sampling during the summer. When comparing these results with the rock slices, it was found that they contain gaps, dissolution surfaces, and diagenetic processes, but they did not retain water due to the temperature. In addition, some of them contain few gaps.

5- Dry density: Through laboratory tests, it was found that the dry density in all stations is not less than (2 g/cm3). As for the fourth station (Sta.4), we see that its dry density is less than most stations, and this appeared clearly in the total porosity values in the stations). Through the rock layers of these stations, we find that they contain gaps and dissolution surfaces. Which was reflected in its density values, and it also appeared that the density is inversely proportional to the porosity and absorption ratio.

6- Absorption: the reults showed that the absorption of rock masses, based on the thin section of the first , second and fourth stations, is low, which is due to the fact that it is effected by diagentic processes, cementation and dolomit, while the value of absorption for the third station was high values because effected by diagentic processes dissolution and sieve texture and increased their absorption capacity .

7- compressive strength: Through the results of testing the compressive strength of the study area samples, it was found that it ranged between (7.784 MPa - 22.126 MPa). These values are low for the compressive strength of the rock samples, indicating the presence of voids in the rock.

8- Tensile strength: The results of finding the tensile strength of the rocks in the study area showed that it was (medium to high) according to the classification (Deere & Miller, 1968). These values indicate the presence of voids, and as shown in the rock slices, the values indicate a close relationship between the strengths, dry densities, and specific weight, as they indicate the weakness of these properties.

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