Iraqi Bulletin of Geology and Mining *Vol.18, No.1, 2022* *p 35 – 46*

ROCK MASS INDEX (RMi) ASSESSMENT FOR THE CARBONATE ROCK MASSES AROUND AL-SALMAN DEPRESSION, SOUTH OF IRAQ

Luay D. Yousif

Received: 09/ 03/ 2021, Accepted: 22/ 11/ 2021
Keywords: Carbonate rocks; Dammam Formation; Discontinuities; RMi; Rock mass; UCS

ABSTRACT

The current work is carried out to classify the carbonate rock masses around the Al-Salman Depression, using the Rock Mass Index (RMi) system. The RMi system uses the uniaxial compressive strength (UCS) of the intact rock and the jointing parameters, which is a combined measure of the block size (or intensity of jointing) and joint characteristics. This method measures the reduction of intact rock strength caused by discontinuities and can be applied in various types of rock engineering works and design, using field observation and measurements, and from empirical relationships. The RMi system was applied to the carbonate rock masses of the Middle Unit of the Dammam Formation (Middle Eocene age), which forms the rock slopes around Al-Salman Depression, Southwest Iraq. The current work. The results of this work denoted that all the rock masses of the studied sites are rated as; “Very High RMi” for sites; 3 and 5, and “High RMi” for the other studied sites. These are due to the “Very Strong” and “Strong” strength, “Massive” and “Blocky” rock masses.

تقييم "دالة الكتلة الصخرية" (**RMi**) للكتل الصخرية الكاربوناتية المحيطة بمنخفض السلمان، جنوب العراق

لؤي داود يوسف

المستخلص

اجري العمل الحالي لتصنيف كتل الصخور الكاربوناتية المحيطة بمنخفض السلمان باستخدام نظام "دالة كتلة الصخرة" (RMi). ان نظام دالة كتلة الصخرة يستخدم فحص المقاومة الأنضغاطية أحادية المحور لمادة الصخر السليم ومعاملات الفواصل التي هي مقياس جامع لحجم الكتلة الصخرية (او كثافة الفواصل) وخصائص الأنقطاعات (الفواصل). هذه الطريقة يمكن تطبيقها على انواع مختلفة من مشاريع تصاميم هندسة الصخور، باستخدام المشاهدات والقياسات الحقلية. تم تطبيق نظام دالة الكتلة الصخرية على الكتل الصخرية الكاربوناتية المكونة للعضو الأوسط لتكوين الدمام (بعمر الأيوسن الأوسط) والمكونة للمنحدرات المحيطة بمنخفض السلمان، جنوب غرب العراق. استخدم في هذا العمل القياسات الحقلية ونتائج التحليلات التي اجريت ضمن ثلاث دراسات سابقة على ذات الكتل الصخرية المدروسة حالياً. بينت نتائج هذا العمل ان جميع الكتل الصخرية للمواقع المدروسة صنفت ذات دالة كتل صخرية تراوحت بين "عالية جداً" كما في الموقعين 3 و 5 و "عالية" في بقية المواقع المدروسة. وهذه تعود الى كون الكتل الصخرية "قوية" و"كتلية" و "لوحية".

Retired Senior Chief Geologist,
e-mail: luayalobaidy1955@gmail.com ; luay_geo79@yahoo.com

ISSN 1311 – 4539
https://doi.org/10.5281/zenodo.7018172
GEOSURV-Iraq: www.geosurviraq.iq
IBGM: http://ibgm-iq.org/
Academic Scientific Journals: www.iasj.net

INTRODUCTION

The Rock Mass is an aggregation of rock material separated by geological discontinuities, most common joints, bedding planes, dyke intrusions, and faults (Bieniawski, 1993). The practice of classifying a rock mass based on defined relationships (Bieniawski, 1989) and providing a unique description based on similar characteristics is known as rock mass classification. One of the primary goals of categorization is to find characteristics that influence a rock mass's behavior and, as a result, split that rock mass into groups. Some of the major rock classification systems, such as Q, RMR, GSI, and RMi, have been well established in the subject of rock engineering.

Palmström (1995 and 1996a and b) proposed the RMi – classification system, which uses a set of geological factors that are well characterized. The RMi can be used in a variety of rock engineering projects, with adjustments made for specific projects or rock usage requirements. This material's basic property is employed in engineering and design. The strength properties of construction materials used in civil engineering and mining are the most significant (Palmström, 1996a). Field measurements, observations, and other empirical relationships can be used to determine the input parameters of RMi (Palmström, 1995).

This RMi method was carried out to classify the rock masses of the carbonate rocks of the Middle Member of the Dammam Formation (Eocene age) that form the rims of the Al-Salman Depression for construction and excavation purposes.

- **Location of the Studied Area**

The Al-Salman Depression lies 130 Km Southwest of Samawa City, South Iraq. It is within the area bounded by the latitudes 30° 20' 10" and 30° 33' 23" N, and the longitudes 44° 28' 25" and 44° 38' 16" E (Fig.1).

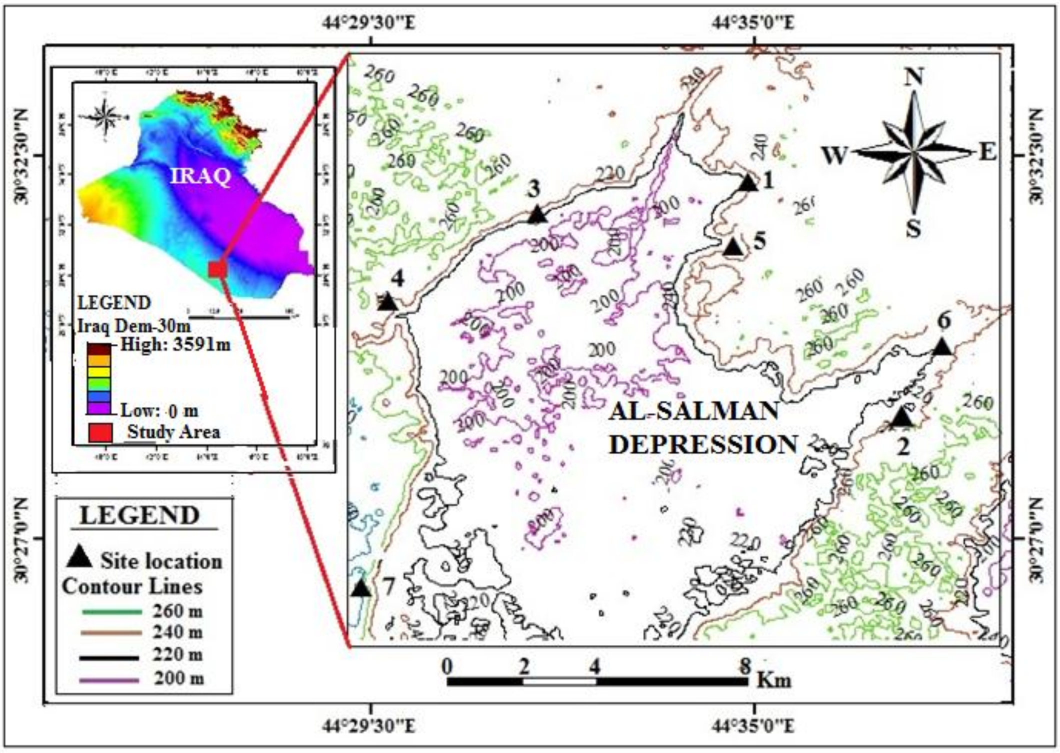

Fig.1: Location map of the Al-Salman Depression, South Iraq (Yousif, 2021)

- **The Aim of this Work**

The studied area is subjected to two previous geological works denoted to the suitability of the rocks as construction and industrial materials could be extracted and exploited as marble substitutes (Ortho-marble) and dimension stone (Arteen and Ameer, 2001) and as raw materials suitable for industrial and construction purposes like limestone for cement production and constructions and dolomitic limestone for glass industries (Kadhum *et al*., 2011).

Accordingly, the main objectives of the current work are to classify the behavior of the carbonate rock masses around the Al-Salman Depression during excavation and mining processes, whenever subjected to exploitation works.

- **Previous Works**

The studied area is located within the Southern Desert of Iraq, which has been subject to different geological studies from the eighties of the last century till today. The current study will focus only on the few geotechnical works conducted in the studied area during the last two decades. These are;

- Arteen and Ameer (2001) carried out a geotechnical study for the substitutes of marble (Ortho-marble) in the Al-Salman area. According to their investigations, the Shawiya Unit of the Middle Member of the Dammam Formation was found to have three economic strata that have acceptable technical specifications for Ortho-marble as a decorative and dimension stone.
- Kadhum *et al*. (2011), according to a work contract for the benefit of Al-Muthanna Governorate Council, conducted a geological investigation on mineral occurrences and industrial rocks. They addressed the availability of rocks that may be used in the cement and glass industries and construction raw materials.
- Yousif *et al.* (2013) assessed the landslide possibility index (LPI) and landslide hazards of the rock slopes of the Al-Salman Depression, demonstrating that three of the studied rock slopes have a very low LPI and the fourth has a low landslide possibility index, suggesting low to moderate hazards, respectively.
- Yousif *et al.* (2014) utilized the rock mass rating (RMR) and slope mass rating (SMR) systems to measure rock mass strength and stability on slopes creating the Al-Salman Depression's margins. They found that most of the studied rock masses are within “Class C” of “Fair” RMR, except sit-5, which is within “Class B” of “Good” RMR, and that all of the studied rock masses are within Class II of Good and Stable, except site 4, which is within Class III of Normal, Partially Stable SMR values.
- Yousif (2021) assessed the excavatability of the carbonate rock masses around Al-Salman Depression, which revealed that “Blasting” is not the only feasible method for excavating the studied rock types, as the “Hard Ripping” using hydraulic machines, is a possible option too.

- **Geology of the Studied Area**

The Al-Salman Depression is a karst landform developed within the Middle Member of the Dammam Formation of the Eocene age (Sissakian *et al.*, 2013). The depression is 20 Km long, with a width of 6.5, 10, and 4.5 km in the northern, central, and southern parts, respectively, and a depth of 5 – 35 meters. The depression's rims are made up of rock slopes with heights ranging from 10 to 35 meters and slope inclinations ranging from 15° to 70°. It is developed by the dissolution of the carbonate rocks of the Dammam Formation by the rainwater, and the underlying anhydrite rocks of the Rus Formation (Early Eocene) by the groundwater. The floor of the depression is filled partly by the Zahra Formation (Pliocene – Pleistocene) and partly by depression fill sediments of the Holocene age (Sissakian *et al.*, 2013).

The studied rock masses consist of the exposures of the carbonate rock masses of the Middle Member of the Dammam Formation (Fig.2). The strata are horizontally lying, locally slightly dipping towards the depression, and dissected by two to three sets plus random joints (Yousif *et al*., 2013). These joint sets are normally dissected in the bedding planes.

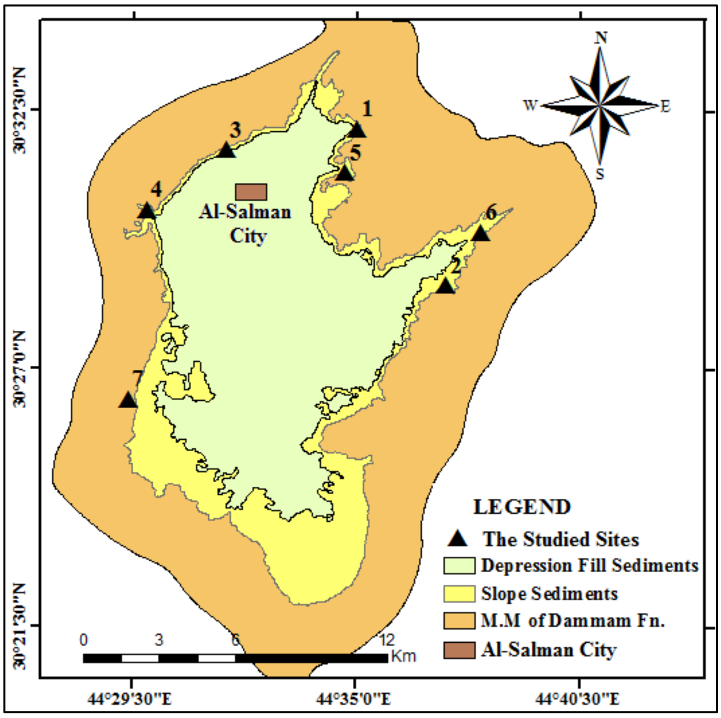

Fig.2: The geological map of the Al-Salman Depression
(After Mahmood *et al*., 2014)

The carbonate rock unit of the Middle Member of the Dammam Formation in the studied area consists of two units. They are described by Sissakian *et al*. (2013) as follows;

- The Shawiya Unit is composed of thickly bedded to massive, recrystallized nummulitic limestone, with thin limestone horizons and (2 – 3) strata of shelly limestone alternation.
- The Chabd Unit; the lower part (15 – 20 m) consists of; massive limestone, which is overlain by thinly bedded, nummulitic limestone, and is followed by massive and crystalline limestone (11 – 14 m). The middle part (5 – 10 m) is made up of an alternation of thick horizons of thickly bedded and nummulitic limestone. The upper 15 meters are made up of heavily bedded nummulitic limestone.

Tectonically, the studied area is located within the Stable Shelf of the Arabian Plate, at about 120 Km southwest of Abu Jir Fault Zone, which represents the eastern boundary between the Stable and Unstable Shelves of the Arabian Plate (Buday, 1973; Buday and Jassim, 1987; Al-Kadhimi *et al*., 1996 and Jassim and Goff, 2006). Precisely, it is located within the Salman Sub-Zone of the Stable Shelf.

FIELD OBSERVATION AND MEASUREMENTS

Seven sites were previously studied in det during two different stages of applications to assess; "the application of the LPI system on the Al-Salman rock slopes (Yousif *et al*., 2013) and "the application of the RMR and the SMR on the rock slopes of the Al-Salman Depression (Yousif *et al*., 2014), respectively. Both of these assessments involved the measurements of the discontinuities characteristics and the intact rock strength. All the previously gained data were listed in Table (1).

Table 1: Field observation and measurements of the studied sites (Yousif *et al*., 2013 and 2014)

Discontinuities	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7
Slope height (m)	9	12	6	33	12	16	28
Slope angle	140/22°	180/32°	155/45°	145/55°	310/34°	240/37°	110/13°
B.P inclination	240/15°	250/13°	070/15°	070/10°	250/10°	100/07°	110/13°
B.P mean spacing	0.26 m	0.32 m	0.33 m	0.40 m	0.38 m	0.75 m	0.81 m
Joint dip of set-1	180/90°	250/90°	215/90°	180/90°	080/90°	075/90°	065/90°
Mean spacing of set-1 (m)	0.44	0.33	0.49	0.35	0.87	0.80	0.58
Joint dip of set-2	252/90°	310/90°	290/90°	262/90°	142/90°	220/75°	160/90°
Mean spacing of set-2 (m)	0.5	0.46	0.34	0.29	1.09	0.44	0.63
Joint dip of set-3	134/90°	165/90°	-	165/90°	220/90°	140/90°	260/90°
Mean spacing of set-3 (m)	0.33	0.38	-	0.5	0.64	0.84	0.65
Joint roughness	Slightly Rough	Smooth	Slightly Rough	Smooth	Rough	Smooth	Rough
Persistence (m)	8 – 10	8	6	7 – 10	3	3 – 10	1 – 3
Aperture (mm)	1 – 5	1 – 5	1 – 5	1 – 5	5 – 10	10 – 20	5 – 10
Infill hardness	Soft	Soft	Hard	Hard	Hard	Hard	Hard
Weathering of joint wall	Slightly	Slightly	Slightly	Slightly	Slightly	Slightly	Slightly
Groundwater	Dry	Dry	Dry	Dry	Dry	Dry	Dry
γ_1	72	72	23	23	90	56	90
γ_2	46	42	30	22	62	90	54
γ_3	62	30	90	83	36	34	36
Intact rock strength (UCS)	50 – 100 MPa	50 – 100 MPa	50 – 100 MPa	50 – 100 MPa	64 MPa	30 MPa	64 MPa
Point Load Index (Is) (MPa)	3.2	3.2	3.2	3.2	2.7	1.08	2.7
Jv-Index (F/m)	8.15	8.33	7.95	10.81	6.26	5.88	6.08

B.P = bedding plans, and "γ_1, γ_2, and γ_3"are the angles between joint sets 1, 2, and 3, respectively.

METHODOLOGY

The current work is an application of the rock mass index (RMi) method suggested by Palmström (1995). This method is currently applied to classify the rock masses of the carbonate rocks of the Middle Member of the Dammam Formation that form the rims of the Al-Salman Depression for construction and excavation purposes.

Palmström (1995) established the RMi to characterize the strength of the rock mass for construction applications. An important issue has been the use of parameters in the RMi, which have the greatest significance in engineering. The RMi is calculated using equation (1) and is based essentially on the decrease in rock strength produced by jointing (Palmström, 1995; and 1996a and b):

$$\mathbf{RMi = \sigma^{ci} \times Jp} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\; (1)$$

Where;

σ^{ci} = the uniaxial compressive strength of intact rock measured on 50 mm samples;

Jp = the jointing parameter. The jointing parameter is a reduction coefficient that represents the impact of joints in a rock mass. The value of JP ranges from 0 for crushed rocks to 1 for intact rocks and is calculated by equation (2);

$$\mathbf{Jp = 0.2\, \sqrt{Jc} \times Vb^{D}} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (2)$$

Where;

Vb is the block volume given in m^{3} and can be determined by the field observation measurements. **D = 0.37 Jc** $^{-0.2}$. It has the values listed in Table (2):

Table 2: **D** values according to **Jc** Values (Palmström, 1995)

Jc =	0.1	0.25	0.5	0.75	1	1.5	2	2.5	3	4	6	9	12	16	20
D =	0.586	0.488	0.425	0.392	0.37	0.341	0.322	0.308	0.297	0.28	0.259	0.238	0.225	0.213	0.203

The joint condition factor (**Jc**) describes the joint frictional characteristics. Barton *et al.* (1974) in their Q-system have chosen the roughness and alteration factors (Jr and Ja) to show the importance of joint dilatancy and shear strength. The joint condition (Jc) factor is determined by the equation (3);

$$\mathbf{Jc = JL\, (JR / JA)} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\; (3)$$

Where;

JL = joint length and continuity factor

JR = joint wall roughness factor measured from the small-scale smoothness and large-scale waviness.

JA = joint wall alteration factor

The ratings of; **JL**, **JR,** and **JA** are factors for joint length and continuity, joint wall roughness, and joint surface alteration, respectively. Their ratings are listed in Tables (3, 4, and 5). The factors **JR** and **JA** are similar to the joint roughness number (**Jr**) and the joint alteration number (**Ja**) in the Q-system. The joint size and continuity factor (**JL**) has been introduced in the **RMi** system to represent the scale effect of the joints.

Table 3: The joint size and continuity factor, **JL**, (Palmström, 1995)

			JL	
JOINT LENGTH	**Term**	**Type**	**Continuous joints**	**Discontinuous joints****
< 0.5 m partings	very short	Bedding, foliation, parting	3	6
0.1 – 1.0 m joint	short/small	joint	2	4
1 – 10 m joint	medium	joints	1	2
10 – 30 m	long/large joint	joints	0.75	1.5
> 30 m	very long/large	joint, seam*) or shear*)	0.5	1

***** Often occurs as a single discontinuity, and should in these cases be treated separately.

****** Discontinuous joints end in massive rock.

Table 4: The rating of joint roughness (**JR**) found from smoothness and waviness (Palmström, 1995)

The small scale of smoothness of the joint surface	**The large scale of the waviness of joint plane**				
	Planer	Slightly Undulated	Strongly Undulated	Stepped	Interlocking (Large scale)
Very rough	3	4	6	7.5	9
Rough	2	3	4	5	6
Slightly rough	1.5	2	3	4	4.5
Smoothed	1	1.5	2	2.5	3
Polished	0.75	1	1.5	2	2.5
Slickenside	0.6 – 1.5	1 – 2	1.5 – 3	2 – 4	2.5 – 5

***** For filled joints: JR=1,
***** For irregular joints a rating of JR = 5 is suggested
***** For slicken-sided joints the value of JR depends on the presence and appearance of the striations; the highest value is used for marked striations

Table 5: Characterization and rating of joint alteration factor (**JA**) (Palmström, 1995)

A- **CONTACT BETWEEN THE TWO ROCK WALL SURFACES**		
Term	**Description**	**JA**
Clean joint: - Healed or welded joints - Fresh rock walls - Alteration of joint walls 1- grade more altered 2- grade more altered Coating or thin filling: - Sand, Silt, Calcite, etc. - Clay, Chlorite, Talc, etc.	Softening, impermeable filling (quartz, epidote, etc.) No coating or filling on the joint surface, except for staining The joint surface exhibits one class higher alteration than the rock The joint surface shows two classes of higher alteration than the rock Coating of friction materials without clay Coating of softening and cohesive minerals	0.75 1 2 4 3 4

B- FILLED JOINTS WITH PARTIAL OR NO CONTACT BETWEEN THE ROCK WALL SURFACES			
TYPE OF FILLING	**Description**	**Partial wall contact Thin filling (< 5mm)* JA**	**No wall contact Thick filling or gauge JA**
- Sand, Silt, Calcite, etc.	Filling of friction materials without clay	4	8
- Compacted clay material	"Hard" filling of softening and cohesive materials	6	10
- Soft clay materials	Medium to low over-consolidation of filling	8	12
- Swelling clay materials	Filling material exhibits clear swelling properties	8 – 12	12 – 20

***** Based on joint thickness division in the RMR system (Bieniawski, 1973)

The concept with RMi is that the joints that intersect a rock mass tend to degrade its strength. As a result, it is defined as RMi = σc JP.

Where, σc = is the uniaxial compressive strength of intact rock (in MPa), measured on 50 mm core diameter or cubic dimension samples. It is applied directly in RMi determination (Palmström, 1996a).

Significant scale effects are generally involved when the tested rock volume is enlarged from laboratory size to field size. The RMi is restricted to large samples where the scale effect has been included in Jp. From data presented by Hoek and Brown (1980); Wagner (1987); and Barton (1990) recommends that the actual compressive strength for large "field samples" (cm) can be estimated using the equation (4), as described by Palmström, 1996a, and b:

$$\sigma_{c^m} = \sigma_{c50}\ (0.05/Db)^{0.2} = \sigma_{c50} \times f\sigma \ .... (4)$$

Where;
σ^{cm} = uniaxial compressive strength of rock mass
σ_{c50} = the uniaxial compressive strength of intact rock measured on 50 mm samples
Db = block diameter measured in meters, which may be obtained from Db = $\sqrt[3]{Vb}$.
fσ = $(0.05/Db)^{0.2}$ is the scale factor for compressive strength.

Equation (4) applies to blocks with diameters ranging from a few millimeters to several meters, and may, therefore, be applied for massive rock masses which were suggested for sites; 1, 2, 3, and 4.

Where irregular jointing occurs, it takes a long time to measure all (random) joints in a joint survey. Hence, it is often considerably faster- and also more accurate- to measure the block volume (Vb) directly in the field in such cases, as well as for other jointing patterns (Palmström, 1996a). Where three regular joint sets occur, the block volume can easily be found from the joint spacing by the equation (5);

$$Vb = (S1 \times S2 \times S3) / (\sin\gamma 1 \times \sin\gamma 2 \times \sin\gamma 3) \ .... (5)$$

Where; γ1, γ2, and γ3 are the angles between the joint sets, and S1, S2, and S3 are the spacing between the individual joints in each set.

In the current work, because the joint planes are perpendicular to the bedding planes, the angles between joint sets γ1, γ2, and γ3 (Table 1) are measured between the strikes of the joint sets, along the exposed surfaces, as shown in Fig. (3) for example. The calculated Vb values are listed in Table (7).

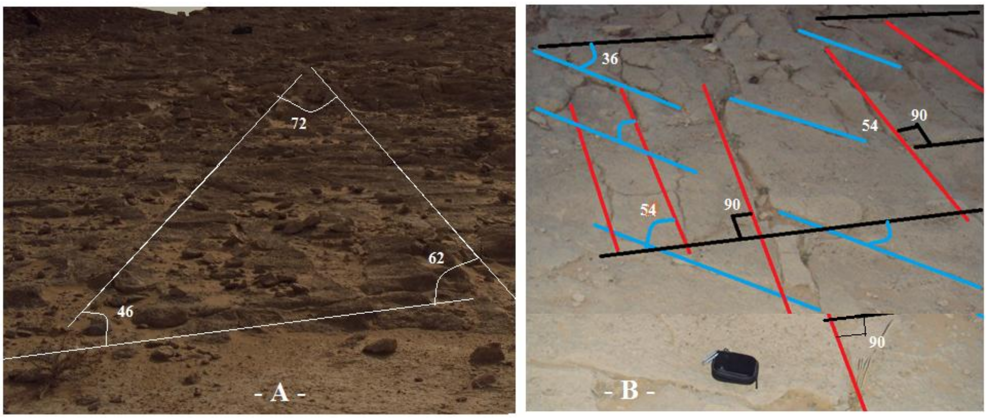

Fig.3: The representation of the angles between joint sets in Site-1(A) and Site-7(B)

Palmström (1995) published the RMi classification as shown in Table (6), which illustrated that the RMi system could be used to categorize extremely weak to extremely strong rocks. When describing the qualities of a complicated material like a granite mass, numerical values are rarely enough. As a necessity, additional descriptions should be included with the RMi and its parameters.

Table 6: Classification of rock mass index (RMi) (Palmström, 1995)

Term		RMi value
RMi	**Related to rock mass strength**	
Extremely Low	Extremely weak	< 0.001
Very Low	Very weak	0.001 – 0.01
Low	Weak	0.01 – 0.1
Moderately Low	Medium	0.1 – 1
High	Strong	1 – 10
Very High	Very strong	10 – 100
Extremely High	Extremely strong	>100

RESULTS AND DISCUSSION

The RMi ratings for the carbonate rock masses of the Middle Member of the Dammam Formation in the Al-Salman Depression have been dependent on the data measured in the field and laboratory tests and office calculations of the three previous studies carried out by Yousif *et al*. (2013 and 2014); and Yousif (2021).

In these works, the uniaxial compressive strength (UCS) for the intact rock materials of sites 5, 6, and 7 were measured, in the laboratories of the GEOSURV, on (50 x 50 x 50) mm cubic rock samples (Yousif *et al.*, 2014). For sites; 1, 2, 3, and 4, the UCS were measured, in the field, by the simple field identification using the geological hammer, according to; ISRM, (1978); Brown, (1981) and (BS 5930, 1981), in which the rock lumps broken by heavy hammer blows to fracture it (UCS = 50 – 100 MPa), and the lower value (50 MPa) is considered, for conservative. So, the σ_{cm} values required are converted to σ_{c50} values according to Eq. (4). The current office calculations are listed in Table (7) following the aforementioned equations.

Table 7: Jc parameters of the studied sites

Parameters	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7
JL	2	2	1	2	1	2	1
JR	2	1.5	2	1.5	3	1.5	3
JA	4	4	4	4	4	4	4
Jc	1	0.75	0.5	0.75	0.75	0.75	0.75
D	0.37	0.392	0.425	0.392	0.392	0.392	0.392
Vb	0.121	0.181	0.859	0.349	1.17	0.639	0.50
Vb^D	0.458	0.512	0.937	0.662	1.063	0.839	0.762
Db	0.495	0.566	0.955	0.705	1.054	0.861	0.794
fσ	0.632	0.615	0.554	0.588	0.542	0.567	0.574
σc_m	50	50	50	50	-	-	-

The JL, JR, and JA values are taken from Tables 3, 4, and 5, respectively. The joint length (JL) values ranged between 1 when they are continuous, and 2, when they are discontinuous because most of the joints are (1 – 10) m in length. Joint roughness (JR) was determined by touch and feel according to ISRM (1978). The ratings of these parameters are based on the Q-system; the joint roughness factor (Jr) in the Q system is, as mentioned, similar to JR. The joint wall roughness (JR) values ranged between 1.5 and 3. They gained 3 when they are planer very rough, 2 when they are "planer rough" and 1.5 when they are "planer slightly rough". The joint alternation or weathering (JA) value is 4 for all of the seven sites because most of the joints are coated or filled partially with thin sand, silt, and calcite, and no contact between the rock wall surfaces. Hence, the calculated joint condition (Jc) values are 1.0 in site-1, 0.5 in site-3, and 0.75 in the other studied sites, as shown in Table (6).

After the application of the Palmström (1995) eq. (1), the final RMi values and ratings are listed in Table (8), which showed that the RMi values of all of the studied sites ranged from 4.4 on site-6 to 11.9 on site-3. It is rated between "**Very High RMi**" (RMi = 10 − 100) and "**Very Strong**" mass strength for sites; 3 and 5, and "**High RMi**" (RMi = 1 – 10) and "**Strong**" mass strength for the other studied sites, according to the RMi rating (Table 5). Accordingly, the resulted RMi classes and values are demonstrated on the location map of the studied sites, as shown in Fig. (4).

Table 8: The RMi values and rating results of the studied sites

Sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$\sigma c_{50\ (MPa)}$	79	81	90	85	64	30	64
Jp	0.091	0.089	0.132	0.114	0.184	0.145	0.132
RMi values	7.2	7.2	11.9	9.7	11.8	4.4	8.4
RMi rating	**High**	**High**	**Very High**	**High**	**Very High**	**High**	**High**
Rock Mass Strength	Strong	Strong	Very Strong	Strong	Very Strong	Strong	Strong

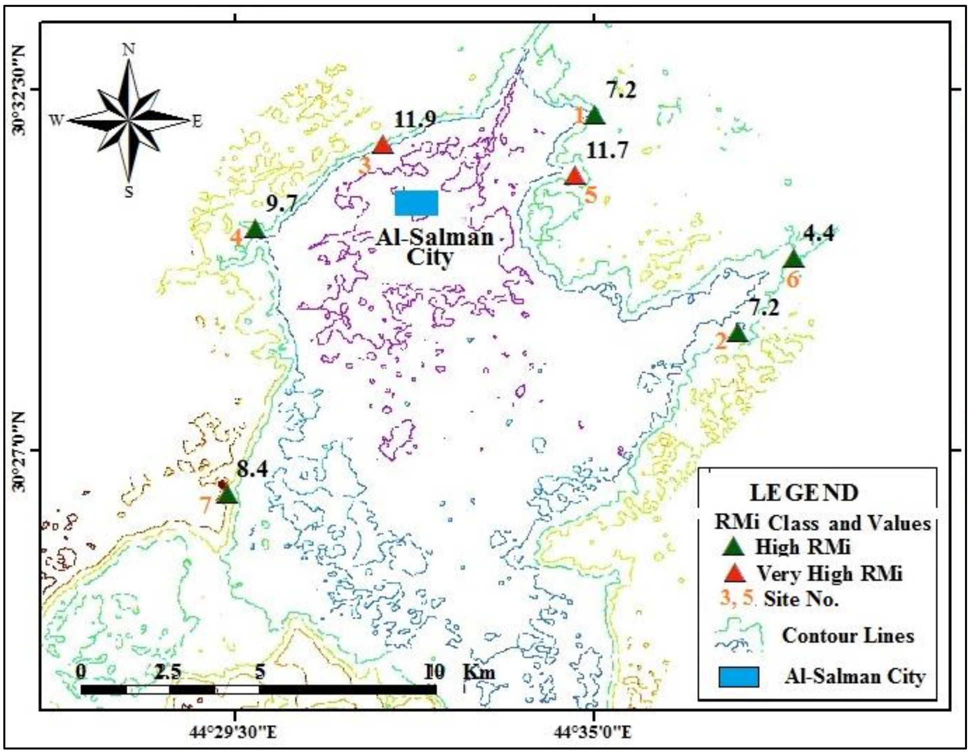

Fig.4: Map showing the RMi classes for the Eocene carbonates rock masses Around the Al-Salman Depression

CONCLUSIONS

The Middle Eocene carbonate rock masses of the Middle Member of the Dammam Formation around the Al-Salman Depression are classified following the Rock Mass index "**RMi**" system in seven sites. The studied rock masses are rated as; "**Very High RMi**" and "**High RMi**" according to the **RMi** rating due to the values that ranged between 4.4 for site-6 and 11.9 for site-3. The "**Very High RMi"** is rated for the rock masses in sites 3 and 5, while the other sites are rated as "**High RMi**". These may be due to the "**Very Strong"** to "**Strong**" strength of the intact rock material and the "Massive" to "Blocky" nature of the rock fabric.

According to the **RMi** classification system, the current results showed some coincidence with previous conclusions of the rock mass rating (RMR) results, which were rated as "**Good**" and "**Fair"** RMR.

The **RMi** classification system can depend only on the field observations and measurements of the joints characteristics and intact rock strength using simple field tests such as; "geological hammer", "Schmidt Hammer", or the portable (field) point load testing device. Hence, the currently used system can be useful in the easy, rapid, and low cost to characterize rock masses, and can be applicable to rock engineering and design such as excavation, construction, and mining.

REMARKS

Pamlström, (1995), mentioned that the value of the jointing parameter (JP) is calibrated from a few large-scale compression tests. Both the evaluation of the various factors (jR, jA, and Vb) used in obtaining JP and the relatively small size of some of the samples tested, may be sources of error in the expression for JP. The value of RMi found may therefore be approximate. In some cases, however, errors in the various parameters may partly have neutralized each other.

ACKNOWLEDGMENT

The author acknowledges his colleagues in the team of the "detailed geological mapping of SW-Samawa region- The third stage, during (2013 – 2014), for their encouragement and contribution to the field measurements of the previous and the current works. Thanks are extended to the geologists and technicians of the Geotechnical Laboratories/ Central Laboratories Department of the Iraq Geological Survey (GEOSURV) for their efforts and cooperation in the geotechnical and petrophysical tests of this study.

REFERENCES

Al-Kadhimi, J.A.M., Sissakian, V.K., Fattah, A.S. and Deikran, D.B., 1996. Tectonic Map of Iraq, scale 1: 1000 000, 2nd edit., GEOSURV, Baghdad, Iraq.

Arteen, A.O. and Ameer, I.A., 2001. Geotechnical investigation for substitutes of marble in Salman area. GEOSURV, int. rep. no. 2746.

Barton, N., Lien, R. and Lunde, J., 1974. Engineering classification of rock masses for the design of tunnel support, Rock Mech., Vol.6, p. 189 – 236.

Barton, N., 1990. Scale effects or sampling bias? Proc. Int. Workshop Scale Effects in Rock Masses, Balkema Publ., Rotterdam, p. 31 – 55.

Bieniawski, ZT., 1973. Engineering classification of jointed rock masses, Transf. S. Afr. Inst. Civ. Eng., Vol.15, p. 335 – 44.

Bieniawski, Z.T., 1989. Engineering Rock Mass Classifications. John Wiley and Sons, New York, 251pp.

Bieniawski ZT, 1993. Classification of rock masses for engineering: The RMR System and future trends, Comprehensive Rock Engineering, Practice and Projects, Rock testing and site characterization (Hudson J.A. ed.), Pergamon Press: Oxford, UK, Vol.3, p. 553 – 573.

Brown, E.T., 1981. Rock characterization testing and monitoring: ISRM suggested methods. Pergamon Press.
BS 5930, 1981. Code of Practice for Site Investigations. British Standards Institution (BSI). London. 147pp.
Buday T., 1973. The Regional Geology of Iraq. GEOSURV, Manuscript Report.
Buday, T. and Jassim., S.Z., 1987. The Regional Geology of Iraq. Vol.2, tectonism, Magmatism and metamorphics. Abbas M.J. and Kassab I.I. (Eds). GEOSURV, Baghdad, 352pp.
Hoek, E. and Brown, E.T., 1980. Underground excavations in rock. Institution of Mining and Metallurgy, London 1980, 527pp.
ISRM (International Society of Rock Mechanics), Commission on Standardization of Laboratory and field tests, 1978. Suggested methods for the quantitative description of discontinuities in rock masses. Int. J. Rock Mech. Min. Sic.& Geomech. Abstr. Vol. 15, No.6, pp. 319-368.
Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, 341pp.
Kadhum, M.A., Awad, A.M. and Tawfeeq, O.A., 2011. Geological investigation for mineral occurrences and industrial rocks in Muthana Governorate. GEOSURV, int. rep. no. 46. (in Arabic)
Mahmood, A.A., Awad, A.M., Bashir, W.P., Al-Kubaisy, K.N., Ali, M.A. and Taufiq, U.A., 2014. Detailed geological survey of south Samawa region, southwest Iraq, scale 1: 25000, 3rd stage. GEOSURV, int. rep. no.3522
Palmström A., 1995. RMi - a rock mass characterization system for rock engineering purposes. Ph.D. thesis, University of Oslo, Norway, 400pp.
Palmström A., 1996a. Characterizing rock masses by the RMi for use in practical rock engineering, Part 1: The development of the rock mass index (RMi). Tunneling and Underground Space Technology, Vol.11, No.2, p. 175 – 188.
Palmström A, 1996b. Characterizing rock masses by the RMi for use in practical rock engineering, part 2: Some practical applications of the rock mass index (RMi), Jour. of Tunneling and Underground Space Technology, Vol.11, Issue 3, p. 287 – 303.
Sissakian, V.K., Mahmoud, A.A. and Awad, A.M., 2013. Genesis and age determination of Al-Salman Depression, South-Iraq. Iraqi Bull. Geol. Min., Vol.9, No.1, p. 1 – 16.
Wagner, H., 1987. Design and support of underground excavations in highly stressed rock. Proc. 6th ISRM Congr., Montreal; Keynote paper Vol.3.
Yousif, L.D., Awad, A.M., Ali, M.A. and Rumaied S.A., 2013. Application of Landslide Possibility Index System (LPI) on rock slopes of Al-Salman Depression, SW, Samawa region, South Iraq. Iraqi Bull. Geol. Min., Vol.9, No.2, p. 15 – 25.
Yousif, L.D., Awad, A.M., Ali, M.A. and Taufiq U.A., 2014. The Application of Rock Mass Rating (RMR) and Slope Mass Rating (SMR) Systems on Rock Slopes of Al-Salman Depression, South Iraq. Iraqi Bulletin of Geology and Mining, Vol.10, No.1, 2014 p. 93 – 106.
Yousif, L.D., 2021. Excavatability Assessment for the Eocene Carbonate Rocks around Al-Salman Depression, SW-Iraq. Iraqi Bull. Geol. Min., Vol.17, No.1, p 1 – 13.

About the author

Mr. Luay Dawood Yousif graduated from Assiut University, Arab Republic of Egypt, in 1979 with B.Sc. in Geology. He got his M.Sc. degree from Baghdad University in 2005, in Rock Slope Engineering Geology. He joined Iraq Geological Survey in 1990 and was nominated as Senior Chief Geologist in 2004. His main field of interest is rock slope stability, rock and soil mechanics, and construction raw materials. He has contributed to many of the Iraq Geological Survey projects, especially in engineering geology and geological mapping. He has many unpublished geological reports and ten (11) published papers.

e-mail: luayalobaidy1955@gmail.com; luaygeo@yahoo.com

Mailing address: Al-Shamasya District, 320, 18, 33, Baghdad, Iraq