THE APPLICATION OF ROCK MASS RATING AND SLOPE MASS RATING SYSTEMS ON ROCK SLOPES OF AL-SALMAN DEPRESSION, SOUTH IRAQ

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Received: 20/ 02/ 2013, Accepted: 28/ 11/ 2013
Keywords: Rock mass, Slope mass, Rock slopes, RQD, Rating, Al-Salman Depression, Iraq

ABSTRACT

An empirical method using Rock Mass Rating (RMR) and Slope Mass Rating (SMR) has been applied based on field observations and measurements, and laboratory tests to estimate the strength of rock mass and to assess the stability of rock masses on slopes forming the edges of Al-Salman Depression, located 130 Km southwest of Samawa city, South of Iraq. This procedure is beneficial for acquiring better understanding for the influence of the geological and rock strength parameters, and the mechanism of rock failure on slope stability analyses and processes of open cast mining and quarrying.

Field observations and measurements were carried out at seven sites along the edges of Al-Salman Depression, where some rock slope failures have occurred. The seven studied sites comprise the rock slopes of the Middle Member of the Dammam Formation (Middle Eocene), which consists of alternation of white, grey and yellowish grey, dolomitic limestone, occasionally, nummulitic and chalky limestone.

Slope mass rating is calculated based on values of Rock Mass Rating and joint and slope orientations. The calculated RMR values involve Class C of Fair Rock Mass and Class B of Good Rock Mass. The calculated values of SMR are within Class II of Good and Stable; in most of the studied slopes, but only one site (site 4) is within Class III of Normal, Partially Stable. The calculated results match some of the site conditions.

تطبيق نظامي تقدير الكتلة الصخرية وكتلة المنحدر على المنحدرات الصخرية لمنخفض السلمان، جنوب العراق

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المستخلص

تم إتباع الأسلوب التجريبي باستخدام تقدير الكتلة الصخرية (RMR) وتقدير كتلة المنحدر (SMR) اعتمادا على المشاهدات والقياسات الحقلية لتقييم استقرارية كتل الصخور على المنحدرات المكونة لجروف منخفض السلمان والذي يبعد 130 كيلومتر جنوب غرب مدينة السماوة في جنوب العراق. إن هذا الأسلوب مفيد في الحصول على معرفة جيدة لتأثير العوامل الجيولوجية ومعاملات قوة الصخرة وميكانيكية انهيار الصخور في تحليل استقرارية المنحدرات وأعمال حفر المناجم المفتوحة والمقالع.

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أجريت القياسات والملاحظات الحقلية على 7 مواقع حصلت فيها حركات الانهيال حول منخفض السلمان. تتضمن هذه المواقع السبعة المنحدرات الصخرية لمكاشف العضو الأوسط لتكوين الدمام (الإيوسين الأوسط)، والذي يتكون من تعاقب حجر الكلس الدولومايتي والذي يكون أحيانا نيوميولايتي مع حجر الكلس الطباشيري، ذو اللون الأبيض والرمادي والرمادي المصفر.

تم حساب تقدير كتلة المنحدر(SMR) اعتمادا على قيم تقدير الكتلة الصخرية (RMR) وخصائص المنحدر والانقطاعات الأخرى والتي بينت أن قيم RMR في المنحدرات المدروسة كانت ضمن رتبة C، ذات الصخور معتدلة القوة ورتبة B، ذات الصخور الجيدة. أما حساب SMR، بين أن كل المحطات ضمن الصنف II، ذو المنحدرات الجيدة والمستقرة لمعظم المحطات المدروسة، باستثناء محطة واحدة فقط (محطة 4) كانت ضمن صنف III، ذو منحدر طبيعي ومستقر أحيانا، وحركات الانهيال المحتملة تحدث لبعض الكتل. أشارت نتائج حساب الكتلة الصخرية وكتلة المنحدر الى بعض التوافق مع الظروف الموقعية للمنحدرات المدروسة.

INTRODUCTION

Seven sites were studied in detail in an attempt to assess the stability of the rock slopes around Al-Salman Depression and to execute training program for the GEOSURV's geologists on slope stability analyses systems. The seven sites are within the rock slopes of the Middle Member of the Dammam Formation that are exposed around Al-Salman Depression (Al-Mubarak and Amin, 1983).

Al Salman Depression is located 130 Km southwest of Samawa city, bounded by latitudes 30° 20' 10'' and 30° 33' 23'' N, and longitudes 44° 28' 25'' and 44° 38' 16'' E (Fig.1).

Geomorphologically, Al-Salman Depression is the largest karst landform in the Southern Desert of Iraq (Sissakian *et al*., 2013). It is of uvala type developed within the Middle Member of the Dammam Formation. The length of the depression is 20 Km, whereas, the width is variable, it is (6.5, 10 and 4.5) Km in the northern, central and southern parts respectively, while, the depth ranges from (5 – 35) m (Sissakian *et al*., 2013).

The edges of this depression consist of rock slopes with heights range between (10 – 35) m and slope inclinations between (15 – 70)°, towards the depression. It is developed by the dissolution of the carbonate rocks of the Middle Member of the Dammam Formation (Middle Eocene) by the rain water, and the underlying anhydrite rocks of Rus Formation (Early Eocene) by the groundwater (Sissakian *et al*., 2013).

Geologically, the studied rock slopes consist of the exposures of the Middle Member of the Dammam Formation. The floor is covered partly by the Zahra Formation (Pliocene – Pleistocene) and partly by depression fill sediments of Holocene age. Tectonically, the studied area is located within the Inner Platform of the Arabian Plat, at about 120 Km southwest of Abu Jir Fault Zone, which represents the eastern boundary between the Inner and Outer Platforms (Fouad, 2012).

▪ Previous Works

Different previous geological studies were executed within the Iraqi Southern Desert, among them are extensive field works executed by many of GEOSURV geologists. In the previous executed works, all geological aspects have been studied among them are:

- Al-Mubarak and Amin (1983) described the regional geology of the Southern Desert, in which the studied area is located.
- Arteen and Ameer (2001), denoted to the presence of ten localities as promising areas for investment of marble substitutes within Shawiya Unit of the Middle Member of Dammam Formation.

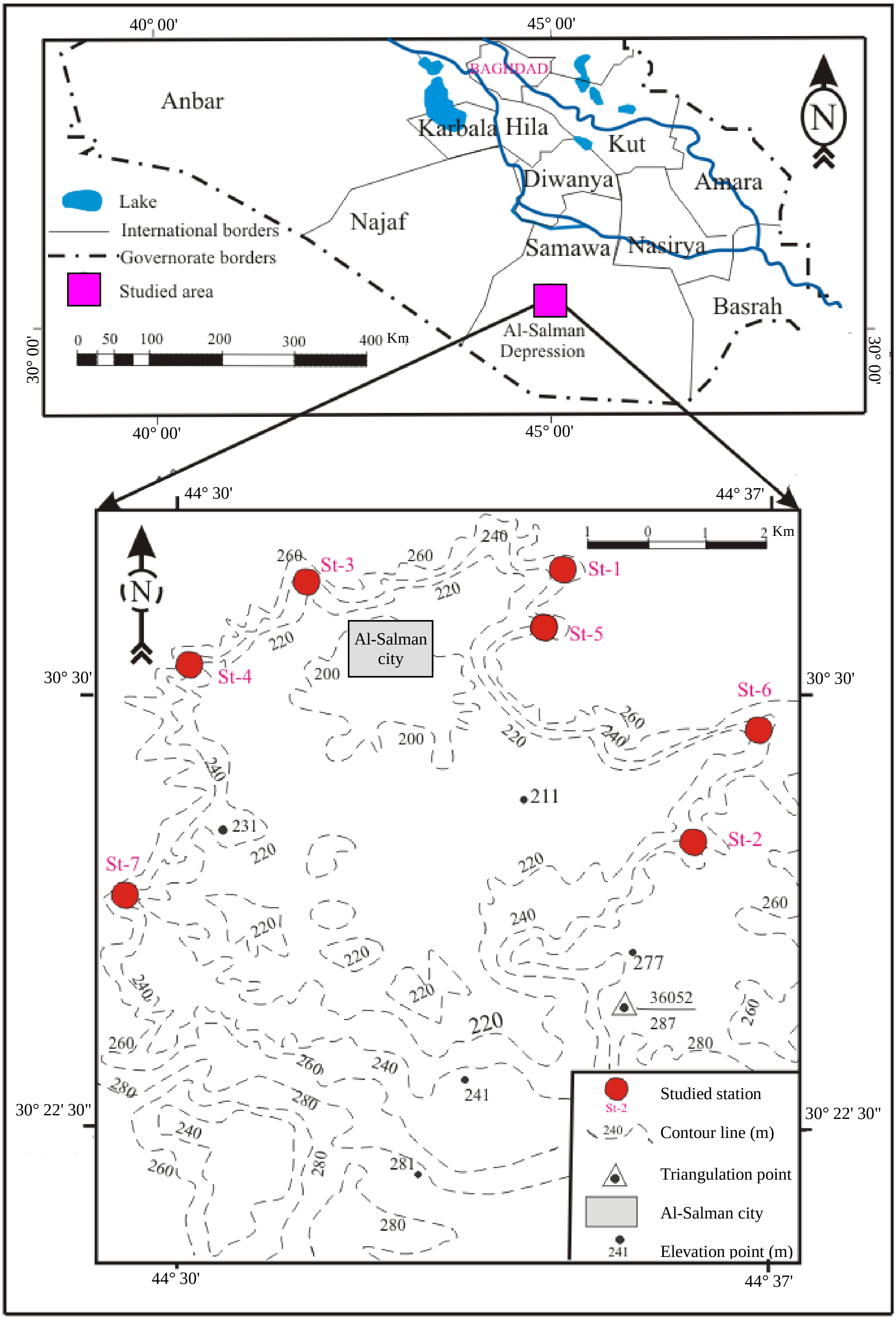

Fig.1: Location and contour maps of Al-Salman Depression

− Ma'ala (2009), Al-Jiburi and Al-Basrawi (2009), and Jassim and Al-Jiburi (2009), described the geomorphology, hydrogeology and stratigraphy, of the Southern Desert of Iraq, respectively.
− Fouad (2012), compiled the tectonic map of Iraq at scale of 1: 1000 000.
− Sissakian *et al*. (2013) studied the genesis and age determination of Al-Salman Depression.
− Yousif *et al*. (2013) determined the landslide possibility index and the landslide hazards of the rock slopes of Al-Salman Depression and denoted that three sites of the studied rock slopes are of Very Low and the fourth is of Low landslide possibility index, and consequently, they are of low hazards to moderate hazards, respectively.

▪ **Methodology**

In many terrains the discontinuities are oriented in such a way that they contribute to create wedge, planar, or toppling failures. These are relatively easy to analyze. In other terrains, most notably flat lying sedimentary rocks with vertical jointing, the predominant failure mechanism tends to be raveling, which is typically not conducive to calculation (Maerz, 2000). These raveling failures are whether slow, time-dependent or fast and catastrophic, which are much more difficult to be analyzed. Hence, the use of empirical design and rock mass classification becomes important. Even though, no analytical tools are available for this task, other tools are available for the practitioner.

Field observations and measurements of discontinuities are the main method for finding the SMR. Geomechanics classification of Rock Mass Rating (RMR) (Bieniawiski, 1989) system has been used to find Slope Mass Rating (SMR) (Romana, 1993).

The RMR (Table 1) is computed according to Bieniawiski (1989) proposal, with adding rating values for five parameters: **i)** strength of intact rock, **ii)** RQD, **iii)** spacing of discontinuities, **iv)** condition of discontinuities, and **v)** water inflow through discontinuities and/ or pore pressure ratio.

Adequate data for the strength of the uniaxial compressive strength was determined according to Hoek and Brown (1997) suggested methods, or any other reliable testing standard. However, often it is necessary to assess strength in the field without the aid of laboratory tests (Romana, 1993). Intact rock strength is established in the field by ‘simple means’ following Table (2), proposed by Hoek and Brown (1997). The method has been extensively tested and compared to the strength determined by the laboratory unconfined compressive strength and point load tests. The assessment of the intact rock strength in the field by ‘simple means’ is obviously partly subjective (Hack, 1996).

The field works were executed in two different stages. The first stage comprised the study of the sites 1, 2, 3 and 4, which was performed at the beginning of 2012 during the study of "Application of Landslide Possibility Index (LPI) on rock slopes of Al-Salman Depression" (Yousif *et al*., 2013), which depends on the field observations and measurements only. While the sites 5, 6 and 7 were studied at the end of 2012, in which some rock samples were obtained and tested by the unconfined (Uniaxial) compressive strength (UCS) test in GEOSURV's laboratories.

Table 1: Rock Mass Rating (after Bieniawiski, 1989)

PARAMETER	INTERVALS						
Unconf. Comp. Str. of intact material (MPa)	> 250	250 − 100	100 − 50	50 − 25	< 25		
					25 – 5	5 – 1	< 1
Rating	15	12	7	4	2	1	0
RQD (%)	100 – 90	90 – 75	75 – 50	50 – 25	< 25		
Rating	20	17	13	8	3		
Spacing of discontinuities	> 2 m	2 – 0.6 m	600 – 200 mm	200 – 60 mm	< 60 mm		
Rating	20	15	10	8	5		
Condition of discontinuities roughness, separation, weathering of joint wall and gouge	Very rough surfaces, No separation, Unweathered wall Not continuous	Slightly rough separation < 1 mm, Slightly weathered wall, Not continuous	Slightly rough Separation < 1 mm Highly weathered wall	Slickensided walls or gouge < 5 mm or separation 1 – 5 mm	Soft gouge >5 mm or separation >5 mm Continuous		
Rating	30	25	20	10	0		
Groundwater in joints (pore water ratio)	Completely dry (0)	Damp (0 − 0.1)	Wet (0.1 − 0.2)	Dripping (0.2 − 0.5)	Flowing (0.5)		
Rating	15	10	7	4	0		

Table 2: Field estimation of intact rock mass strength (Hoek and Brown, 1997)

Term	Uniaxial Comp. Strength (σ_c) (MPa)	Point Load Index (I_s) (MPa)	Field estimate of strength
Extremely Strong	>250	>10	Rock material only chipped under repeated hammer blows
Very Strong	100 – 250	4 – 10	Requires many blows of a geological hammer to break intact rock specimens
Strong	50 – 100	2.4	Hand held specimens broken by single blow of geological hammer
Medium Strong	25 – 50	1.2	Firm blow with geological pick indents rock to 5 mm, knife just scrapes surface
Weak	5 – 25	**	Knife cuts material but too hard to shape into triaxial specimens
Very Weak	1 – 5	**	Material crumbles under firm blows of geological pick, can be shaped with knife
Extremely Weak	0.25 – 1	**	Indented by thumb nail

* All rock types exhibit a broad range of uniaxial compressive strengths, which reflect heterogeneity in composition and anisotropy in structure. Strong rocks are characterized by well interlocked crystal fabric and few voids.
** Rocks with uniaxial compressive strength below 25 MPa are likely to yield highly ambiguous results under Point load testing.

Rock Quality Designation (RQD) was defined according to Deere (1964) as “the total length of all the pieces of sound core over 10 cm length, expressed as a percentage of the total length drilled. Palmstrom (1982) proposed an approximate correlation between RQD and Jv; the volumetric joint count (Jv is the number of joints per cubic meter), which can be used to estimate RQD when drill cores are not available”.

$$RQD = 115 - 3.3\ Jv$$

where: $Jv = \sum (1/Si)$
Si is the mean spacing for the discontinuities of family i

Because there was no available core during the first stage of the work, the aforementioned relationship was used in RQD determination in the current study.

Spacing of discontinuities is the distance between them, measured along a line perpendicular to discontinuity planes. Condition of discontinuities is a very complex parameter, which includes several sub-parameters: **i)** roughness, **ii)** separation, **iii)** filling material, **iv)** persistence, and **v)** weathering of walls (Bieniawiski, 1989) (Table 3).

Table 3: Guidelines for classification of discontinuity conditions (Bieniawiski, 1989)

Persistence	< 1 m	1 – 3 m	3 − 10 m	10 − 20 m	> 20 m
Rating	6	4	2	1	0
Separation (aperture)	None	< 0.1 mm	0.1 − 1.0 mm	1 – 5 mm	> 5 mm
Rating	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slicken sided
Rating	6	5	3	1	0
Infilling (gouge)	None	Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly	Moderately	Highly	Decompose
Rating	6	5	3	1	0

The groundwater, which accounts for the influence of the water pressure, with particular reference to the underground excavation is classified either; completely dry, damp, wet and dripping or flowing (Bieniawiski, 1989). During the field measurements, the studied rock slopes were determined as dry. But, for RMR calculation purposes, the studied rock slopes were rated as wet to consider the worst case, which happens during the rainy seasons and leads to rock failure. The meaning of the final rock mass rating is shown in Table (4), where also the stand-up times for underground excavations, cohesion and friction angle of the rock mass are presented.

Table 4: Rock mass classes determined from total ratings and meaning (Bieniawiski, 1989)

RMR Ratings	**(81 − 100)**	**(61 − 80)**	**(41 − 60)**	**(21 − 40)**	**(< 20)**
Rock mass class	A	B	C	D	E
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock
Average stand-up time	10 year for 15 m span	6 months for 8 m span	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 0.5 m span
Rock mass cohesion (KPa)	> 400	300 – 400	200 – 300	100 − 200	< 100
Rock mass friction angle	> 45°	35° − 45°	25° − 35°	15° − 25°	< 15°

The "Slope Mass Rating" (SMR) is obtained from RMR by adding a factorial adjustment factor; depending on the relative orientation of joints and slopes and another adjustment factor depending on the method of rock slope excavation.

$$SMR = RMR + (F_1 \times F_2 \times F_3) + F_4$$

The adjustment rating for joints (Table 5) is the product of three factors, as mentioned hereinafter:

i) F_1 depends on parallelism between joints and slope face strike. Its range is from 1.00 to 0.15. Romana (1985) gave these values empirically, but these values match the following relationship that he proposed:

$$F_1 = (1 - \sin A)^2$$

where: A denotes the angle between the strikes of slope face and joints, with its absolute value.

ii) F_2 refers to joint dip angle in the planar mode of failure. Its value varies from 1.00 to 0.15, and matches the relationship:

$$F_2 = \tan^2 B_j$$

where: B_j denotes the joint dip angle. For the toppling mode of failure; F_2 value remains 1.00.

iii) F_3 reflects the relationship between slope face and joints dip angles. In planar mode of failure, F_3 refers to the probability that joints "daylight" in the slope face. Condition is Fair (stable), when slope face and joints are parallel. When the slope face dips more than the joints, very unfavorable (daylight) condition occur. Bieniawiski (1989) figures have been kept (all are negative).

iv) F_4 refers to the adjustment factor for the method of excavation has been fixed empirically, (Table 5).

Table 5: Adjustment rating for joints (after Romana, 1985)

Case	**Very Favorable**	**Favorable**	**Fair**	**Unfavorable**	**Very unfavorable**
P $a_j - a_s$ T $a_j - a_s - 180^o$ P/T $F_1 = (1 - \sin a_j - a_s)^2$	> 30° 0.15	30° – 20° 0.4	20° – 10° 0.7	10° – 5° 0.85	< 5° 1.00
P B_j P $F_2 = \tan^2 B_j$ T F_2	< 20° 0.15 1.00	20° – 30° 0.4 1.00	30° – 35° 0.7 1.00	35° – 45° 0.85 1.00	> 45° 1.00 1.00
P $B_j - B_s$ T $B_j - B_s$ P/T F_3	> 10° < 110° 0	10° – 0° 110° – 120° – 6	0° > 120° – 25	0° – (– 10°) – – 50	< – 10° – – 60
F_4 Adjusting factor for excavation method	Natural slope + 15	Pre-splitting + 10	Smooth blasting + 8	Blasting or mechanical 0	Deficient blasting – 8

P- Planar failure a_s- Slope dip direction a_j- Defect dip direction
T- Toppling failure B_s- Slope dip B_j- Defect dip

SMR addresses both planar sliding and toppling failure modes, no additional consideration is made for sliding on multiple joint planes. Finally, rated SMR values are classified, as described in Table (6).

Table 6: SMR Classes defined by Romana (1993)

Class	SMR	Description	Stability	Failures	Support
I	81 − 100	Very good	Completely stable	None	None
II	61 − 80	Good	Stable	Some blocks	Occasional
III	41 − 60	Normal	Partially stable	Some joints or many wedges	Systematic
IV	21 − 40	Bad	Unstable	Planner or big wedges	Importance/ Corrective
V	0 − 20	Very bad	Completely unstable	Big planner or soil like	Re-excavation

MEASUREMENTS AND CALCULATIONS

Field observations and descriptions in the seven sites showed that the slope forming materials are horizontal to locally inclined sedimentary strata mainly composed of alternations of white, yellowish grey and grey dolomitic limestone, fine crystalline limestone; occasionally Nummulitic with chalky limestone. The field observations and measurements show that these rocks are moderately to thickly bedded, slightly weathered, dissected by two to three sets of vertical joint planes with moderate to widely spaced joints and intact rock strength between (30 −100) MPa.

Although data calculations showed that the studied rock slopes are stable, but suffered from some rock failures of raveling type (Fig.2A, B and C, and Fig.3D, E and F); due to the differences in temperature, rain water and seasonal streams water. In terrains, where most notably flat lying sedimentary rocks with vertical jointing, where planar and wedge slides are unusually not found, the predominant failure mechanism being of the raveling type is even greater (Maerz, 2000).

The results of the two stages of observations and measurements are summarized in Table (7). The intact rock strength of the studied rock slopes of the sites 1, 2, 3 and 4 were determined in the field by simple means with the geological hammer, while for the sites 5, 6 and 7 were determined using rock samples, in the laboratory by unconfined (Uniaxial) compressive strength test; as listed in Tables (2 and 7), respectively. The calculated values of Jv index, from which RQD values were obtained, are listed in Table (8), while discontinuity conditions and the adjustment factors (F_1, F_2, F_3 and F_4) are listed in Table (9).

A

B

C

Fig.2: **A**, **B** and **C** raveling failures in stable slopes at the sites 1, 2 and 3, respectively

D

E

F

Fig.3: **D** Side view for the site 4, **E** and **F** frontal views,
for the sites 6 and 7, respectively

According to the field observations, the surface water, especially rainfall, is the main factor triggering rock slopes instability in Al-Salman Depression, although, the Southern Desert is affected by semi arid climatic conditions. Dry ground water condition (Table 7) was considered at the studied sites during the measurement times, but for calculation purposes, the authors suggested the wet condition (Table 9) in which the worst case and rock failures took place during the rainy seasons.

Table 7: Laboratory tests and field observations and measurements of the studied sites within rock slopes of Al-Salman Depression

Site No. / PARAMETERS	1	2	3	4	5	6	7
Slope height (m)	9	12	6	33	12	16	28
Slope inclination	140/22º	180/32º	155/45º	140/55º	310/34º	240/37º	110/13º
B.P. inclination	240/15º	250/13º	070/15º	070/10º	250/10º	100/07º	110/13º
B.P. mean spacing (m)	0.26	0.32	0.33	0.40	0.38	0.75	0.81
Joint dip (set-1)	180/90º	250/90º	215/90º	180/90º	080/90º	075/90º	065/90º
Mean spacing (m)	0.44	0.33	0.49	0.35	0.87	0.80	0.58
Joint dip (set-2)	252/90º	310/90º	290/90º	262/90º	142/90º	220/75º	160/90º
Mean spacing (m)	0.5	0.46	0.34	0.29	1.09	0.44	0.63
Joint dip (set-3)	–	–	–	165/90º	220/90º	140/90º	260/90º
Mean spacing (m)	–	–	–	0.5	0.64	0.84	0.65
Joint surface roughness	S. rough	Smooth	S. rough	Smooth	Rough	Smooth	Rough
Persistence (m)	8 –10	10	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	S	S	S	S	S	S	S
Groundwater	dry	dry	dry	dry	dry	dry	dry
Intact rock strength (MPa)	50 – 100	50 – 100	50 – 100	50 – 100	64	30	64
Density (gm/cm³)	–	–	–	–	2.64	2.16	2.49
Slake durability (%)	–	–	–	–	99.29	96.17	98.72
Elasticity moduli (MPa)	–	–	–	–	3.16	1.68	3.17

S = Slightly

Table 8: The results of Jv index calculations and RQD values in the studied sites

Site No.	1	2	3	4	5	6	7
Jv index value	8.15	8.33	7.95	10.81	6.26	5.88	6.08
RQD value (%)	88	88	89	79	94	96	95

The RMR and SMR calculation results are listed in Table (9), which shows that the RMR values belong to; Class C for the sites 1, 2, 3, 4, 6 and 7, whereas only the site 5 has Class B, which's RMR value is 60. Bieniawiski (1989) described Class C as Fair rocks, while Class B as Good rocks (Table 4).

SMR values show that the sites 1, 2, 3, 5, 6 and 7 were classified within Class II, which is described as Good, Stable, but failures of some blocks could occur; however, only the site 4 is classified within Class III, which was described as Normal, Partially Stable and failures of some blocks could occur (Table 6, Romana, 1993).

Table 9: RMR rating and SMR rating results of the studied rock slopes of Al-Salman Depression

Parameters ratings	Site No.	1	2	3	4	5	6	7
U.C.S.	Value	50 − 100	50 − 100	50 − 100	50 − 100	63.7	30.9	63.9
	Rating	7	7	7	7	7	4	7
RQD	Value	88	88	89	79	94	96	95
	Rating	17	17	17	17	20	20	20
Joint spacing	Value	0.40	0.37	0.39	0.35	0.75	0.71	0.67
	Rating	10	10	10	10	15	15	10
Joint condition	Value							
	Rating	13	16	10	13	13	10	16
Groundwater	Value	Wet	Wet	Wet	Wet	Wet	Wet	Wet
	Rating	7	7	7	7	7	7	7
RMR		54	57	51	54	62	56	60
F1	Value	80	70	265	25	168	320	0
	Rating	0.15	0.15	0.15	0.4	0.4	0.15	1
F2	Value	15	12	15	90	90	07	13
	Rating	1	1	1	1	1	1	0.15
F3	Value	37	44	60	135	124	44	0
	Rating	0	0	0	− 25	− 25	0	− 25
F4	Rating	15	15	15	15	15	15	15
SMR	Value	69	72	66	59	67	71	71
	Class	II	II	II	III	II	II	II
Description		Good − Stable	Good − Stable	Good − Stable	Normal − Partially Stable	Good − Stable	Good − Stable	Good − Stable

RESULTS

According to Bieniawiski (1989) and Romana (1993) classifications, the calculations of both RMR and SMR ratings for the studied rock slopes (Table 9) show that most of the studied sites of Al-Salman Depression are of Class II (in SMR), which were described as; Good, Stable condition, but some block failures could occur in these natural slopes. Although, only the rock slopes at the site 4 is classified as Class III and described as Normal, Partially Stable, but it is close to the Class II because its SMR value is 59.

DISCUSSION

The SMR results showed that all the seven studied sites in Al-Salman Depression are structurally stable, because the strata are semi horizontally lying, the discontinuities are vertical and no discontinuity planes occur along which rock failure can take place along. Hence, all the studied sites are nearly similar in their characteristics (Good and Stable), but some of rock failures of raveling type can occur by gravity only; due to rain and seasonal stream water.

CONCLUSIONS

- Due to the general gentle inclination (10 − 15)° of the beds towards the depression, the same constituents of the beds in all the studied relatively gentle rock slopes, which are dissected by vertical joints; therefore, the slopes are described with similar or closely RMR and SMR ratings.
- The studied rock slopes are described as Fair to Good rock mass and Normal to Good slopes, Partially Stable to Stable. So, the rock slopes are stable, but some block failures occur of raveling type; after removing the underlying support by rain and seasonal stream water.
- According to RMR and SMR systems, the current results showed some coincidence with the real situation of the studied rock slopes in Al-Salman Depression. Hence, the currently used systems can be useful in the easy, rapid and low cost empirical rock slope studies.

RECOMMENDATIONS

From the authors point of view; the aforementioned studied rock slopes, which are developed in a desert environment, relatively far from the nearest urban aggregations (Al-Salman town) and any infrastructure, and because only raveling (rock failure) occur, due to differential weathering by low rates of rain and seasonal stream water; therefore, such studies are useful in urban development designs and planning, in such cases, there is need to execute such studies, when the sites are close to such rock slopes.

ACKNOWLEDGEMENTS

The authors acknowledge their colleagues in the "detailed geological mapping of SW Samawa region", for their encouragement of the previous and current field 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.

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