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Assessment of rock Slope Stability on Shaqlawa – qoysinjaq Road, North Eastern Iraq by using kinematic analysis

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ABSTRACT

This study aims to assess the stability of the rock slopes on both sides of the road linking (Shaqlawa- qoysinjaq) to some of the exposed geological formations within the northeastern limb of the Safin anticline (Qamchuqa, Bakhma, Shiranish), where (6) stations were selected and a classification was made. An engineering description of the rock layers through a comprehensive survey of the study area, the results of the kinematic analysis by the kinematic analysis software (DIPS) showed that the possible percentage failures were represented by rock toppling (83.33%), planar sliding by (58.33%) and then wedge sliding by percentage (83.34%), By studying the factors affecting the stability of slopes in the region, it was found that the main factor causing the failures is the result of cutting the fold for the purpose of road construction, in addition to the structural and lithological factors.

1- Introduction

The instability of rocky slopes is one of the most important problems and risks facing a geologist in his work, complementing the work of a civil engineer.Where these problems appear frequently in the form of landslides in the surrounding slopes or on which roads, railways and public facilities are based, as well as when building roads for the passage of vehicles and railways, or making the necessary designs for digging tunnels, mines, dams, and others. Earth's gravitational force effect it is the main factor in the sliding process on the rock masses or the soil forming the slope. and whenever it was rock mass strength the components of the slope are equal to or greater than the force of gravity on the ground this means that the rock mass is balanced and stable .But when the balance is imbalanced, this will lead to the instability of the rock masses and the failures of the slope which may lead to closing roads or destroying public facilities and endangering human life [1].

From previous studies on the topic of research a study[2] entitled (An engineering geological study of the stability of the rocky slopes along Qalchoalan - Al-Sarkalat – Konamasi Road, Sulaymaniyah, Kurdistan region, northeastern Iraq). It studied and classified the rocky slopes using SMRTool-v205 and DIPS-v6 programs .008 for slope stability and motion analysis.

2- Location of study area: The study area is Located (shaqlawa) distric which is NE of Iraq on road linking Shaqlawa – qoysinjaq where the failure took place on the rock slopes and causes several problems on the road. Six stations were selected in this study as shown in the figure (1).

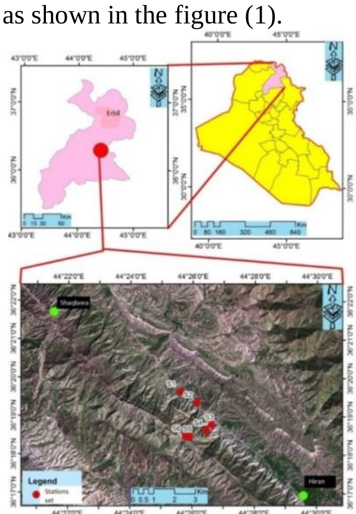

Fig. 1; The site map of the studies area and 6 stations location.

Aims of study

1- Determining failures probability and their expected types, and determine the type of failure expected to occur.

2- Determining the percentage of potential failure.

3- Geology

The rocks that exposed in the study area are ranged in age from Hetrovian to Maastrichtian and represented by Qamchuqa, Bekhme and Shiranish formations (Fig. 2). According to[3] ,**Qamchuqa Formation** (Hetrovian _ Albian) consist of thick layers of limestone and divided into two units, the lower unit by age (Parmian-Abtian), and the higher unit (Albian). This formation appears in station(4,5,6),[3],[4]. **Bekhma Formation** (upper Campanian - lower Maastrichtian) Consists of Limestone and Dolomitic-Limestone,[5,6].

Shiranish Formation (Late Campanian - upper Maastrichtian) is divided into two parts, the bottom of which consists of limestone, which is sometimes marly or white to light gray Clayey, well bedded and with smooth surfaces. As for the upper part of the formation, it consists of shale and marl clay, blue and bluish-grey, and the shale clay gives the formation the papery appearance ,this formation appears in stations (1,2,3), [3].

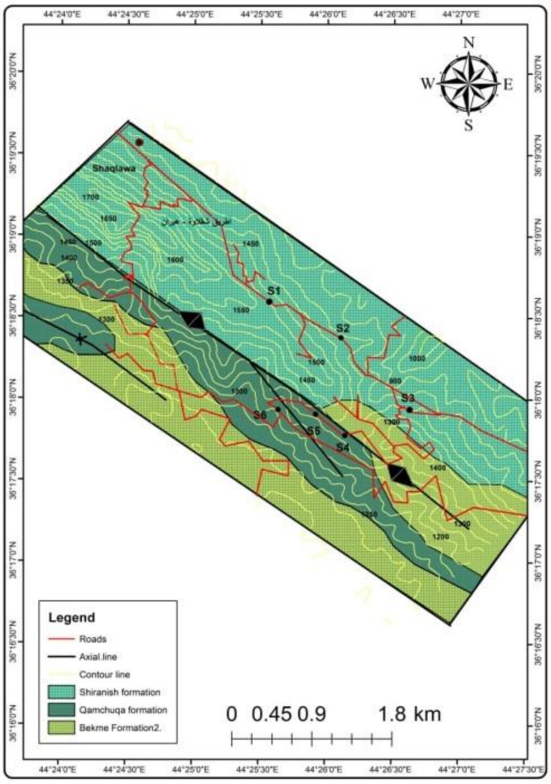

Fig. 2: Geologic map of the studied area.

4- Methodology

This research consist of the field work to conduct a geological field visits the studied area to identify geological, structural, stratigraphic and geomorphological formations of the area. Also to identify the sites of existing or potential failures to nominate ideal sites for study stations, And engineering geological survey of the locations of the stations in which it occurred or there is a possibility of rock slides as in the following steps:

1- Determining the location of each station by a GPS device and recording the coordinates in (UTM) units and the height of the station above sea level in meters.Table (1).

2- Measuring the width and height of the slope using a tape measure..

3- Determining the attitude of slope position and layers (slope value/slope direction). Table (1).

4- Carrying a detailed survey of the discontinuities, represented by the attitude (Dip angles & directions), their types, frequency, the distance between the discontinuities, their extension on the bedding plane and the aperture. Table (1).

5- Determining the occurrence and potential failures.

Table 1: Field data for the selected stations

Station no.	Formations type	dip/dip direction of slope	dip/dip direction of beds	dip/dip direction set 1	dip/dip direction of set 2	internal friction angle ϕ
1	Shiranish formation	45/022	60 /040	79/182	85/300	31
2		62/018	62/018	75/116	67/265	34
3		30/034	30/034	80/118	75/012	32
4	**Qamchuqa Formation**	20/018	20/018	88/344	85/081	32
5	**Qamchuqa Formation**	16/000	16/000	57/160	82/222	35
6	**Qamchuqa Formation**	16/230	16/230	50/044	85/128	30

Types of Failures in Rock Slopes

According to [1] the slope failures classified , Figure (3), including a classification, which classified the failures according to the nature and speed of movement, the shape of the surface of the failures, and the nature of the failures rock masses. And [7] classification, which classified the main types of collapse into**:**

1. Sliding (Planar, wedge, Rotational)
2. Toppling (Block, Flexural, Block -Flexural)
3. Rockfall
4. Rolling

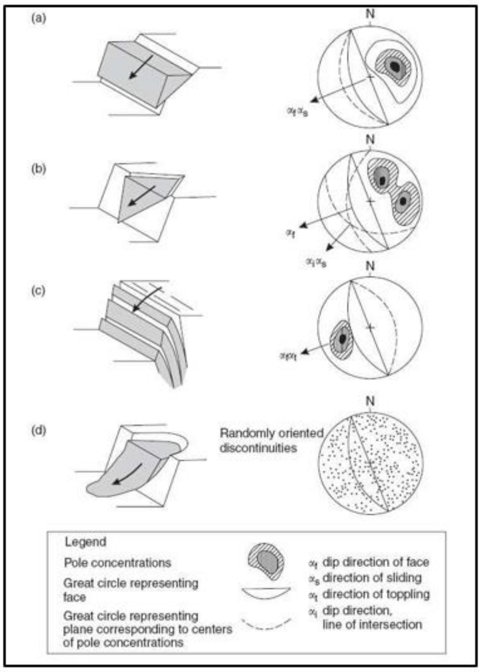

Fig. 3: The main types of Failures [8] where (a) planar sliding, (b) wedge sliding(c) Toppling(d) rotational sliding

Results and discussion

The software (Dips) designed for the interactive analysis of orientation based on geological data. Dips allow the user to analyze and visualize structural data following the same techniques used in manual stereonets. In addition, it has many computational features, such as statistical contouring of orientation clustering, mean orientation and confidence calculation, cluster variability, and qualitative and quantitative feature attribute analysis.

To work on the kinetic analysis program (DIPS), whose interface consists of a worksheet similar to the worksheet in the EXCEL program figure(4), the data was entered represented by determining the attitude slope faces (dip/dip direction), followed by the attitude of the discontinuities (joints and bedding), and then from the contour preset instruction, figure(4) we get a plot representing the projection of the slope face and discontinuities, figure(5), then through the analysis instruction we choose the nematic analysis, and a window appears containing fields for the layer attitude and the angle of internal friction and the types of failures, figure(6) in each attempt we choose a type of failure, and the program gives us the percentage of the probability of its occurrence, figure (7).

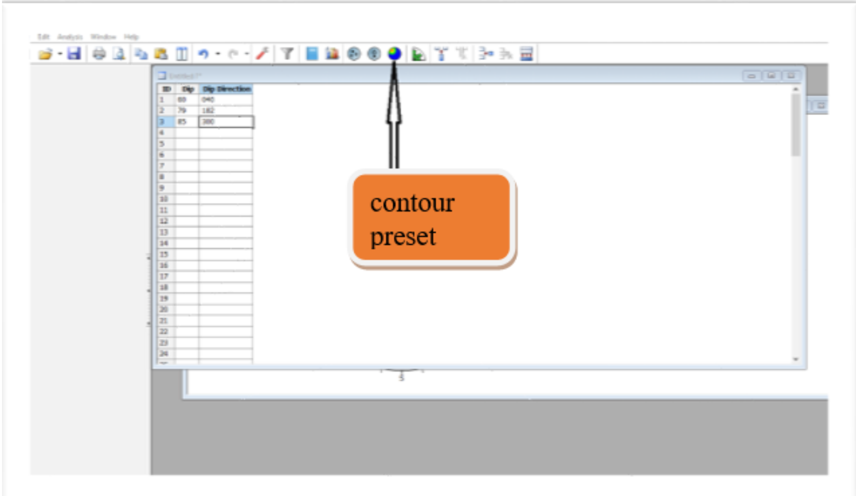

Fig. 4: the kinetic analysis program (DIPS) interface.

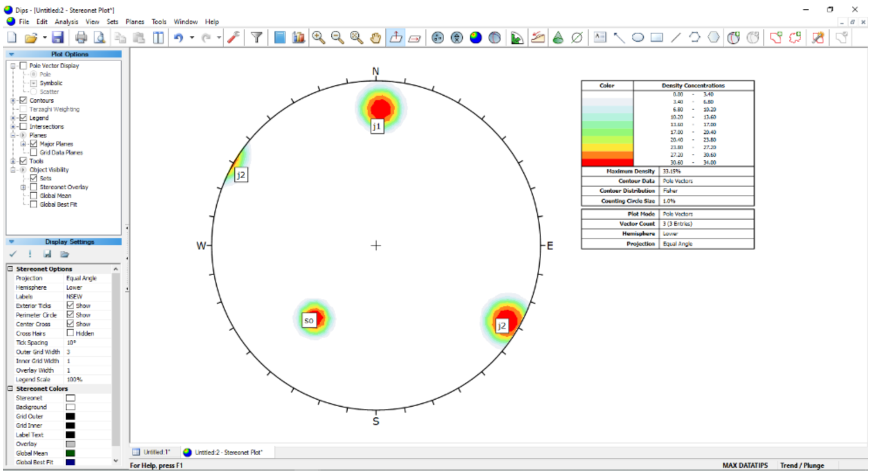

Fig. 5: the projection of the slope face and discontinuities

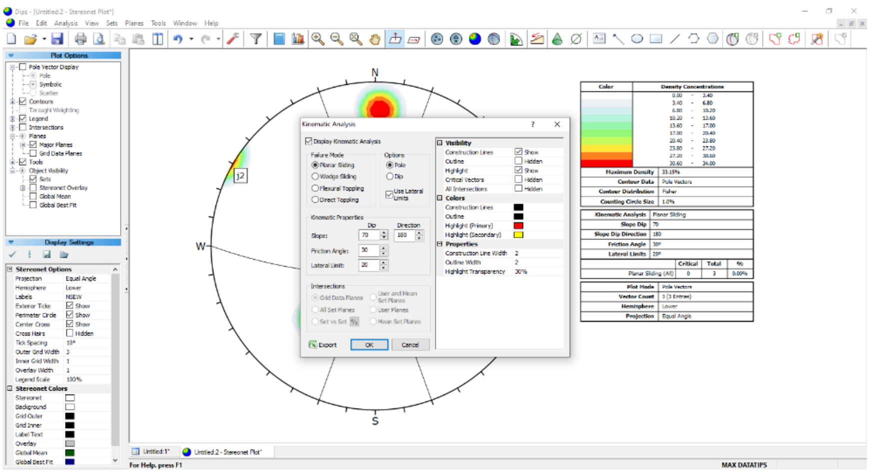

Fig. 6: nematic analysis

Color	Density Concentrations
	0.00 - 3.40
	3.40 - 6.80
	6.80 - 10.20
	10.20 - 13.60
	13.60 - 17.00
	17.00 - 20.40
	20.40 - 23.80
	23.80 - 27.20
	27.20 - 30.60
	30.60 - 34.00
Maximum Density	33.15%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding		
Slope Dip	60		
Slope Dip Direction	40		
Friction Angle	31°		
Lateral Limits	20°		
	Critical	Total	%
Planar Sliding (All)	1	3	33.33%

Plot Mode	Pole Vectors
Vector Count	3 (3 Entries)
Hemisphere	Lower
Projection	Equal Angle

Fig. 7: Percentage probability of failure.

• Station No. (1):

This station is located in the northeastern limb of the Safin anticline, to the right of the street within the Shiranish formation, within the following coordinates: (X=448561), (Y=4020405), and elevation above sea level (Elv=1060 m) in UTM units, which were determined by the (GPS). The station consists of a slope whose attitude is (60/040), with a height of (12 m) and width (60 m).There are three sets of discontinuities, the first group (set1) and its attitude (79/182) and the distance between the discontinuities (frequency = 3 per meter) and represents a release surface, while the second group (set2) and its attitude (85/300) and the distance between the discontinuities (frequency = 3 per meter) and represents a back sliding surface and the third group (set3) and its attitude in the same position with the bedding plane (ab), Concordant with it.The results of the kinematic analysis of station No. (1): (A) there is a possibility of a planar sliding (33.33%), figures (8),(9) , (B) there is a possibility of a wedge sliding (66.67%), figures (10),(11) (C) there is possibility of a flexural toppling,(33.33%) figures (12),(13) (D) There is a possibility of a direct toppling (33.33%), figures(14),(15), where (SF) the face of the slope, (SO) the bedding plane (J1, J2), the sums of the discontinuities.

The potential failures resulting from the program are similar to some field data that represent the failure that actually occurred, such as planar sliding and wedge sliding.

The figures for the first station have been attached only, due to the large number of shapes, where each station has eight shapes

Color	Density Concentrations
	0.00 - 3.40
	3.40 - 6.80
	6.80 - 10.20
	10.20 - 13.60
	13.60 - 17.00
	17.00 - 20.40
	20.40 - 23.80
	23.80 - 27.20
	27.20 - 30.60
	30.60 - 34.00
Maximum Density	33.15%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding		
Slope Dip	60		
Slope Dip Direction	40		
Friction Angle	31°		
Lateral Limits	20°		
	Critical	Total	%
Planar Sliding (All)	1	3	33.33%

Plot Mode	Pole Vectors
Vector Count	3 (3 Entries)
Hemisphere	Lower
Projection	Equal Angle

Fig. 8: The percentage of the Planar sliding in station 1

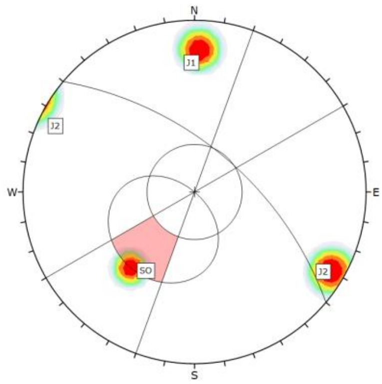

Fig. 9: Planar sliding in station 1

Symbol	Feature
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 3.40
	3.40 - 6.80
	6.80 - 10.20
	10.20 - 13.60
	13.60 - 17.00
	17.00 - 20.40
	20.40 - 23.80
	23.80 - 27.20
	27.20 - 30.60
	30.60 - 34.00
Maximum Density	33.09%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding		
Slope Dip	45		
Slope Dip Direction	22		
Friction Angle	31°		
	Critical	Total	%
Wedge Sliding	2	3	66.67%

Plot Mode	Pole Vectors
Vector Count	3 (3 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	3
Hemisphere	Lower
Projection	Equal Angle

Fig. 10: The percentage of the wedege sliding in station 1

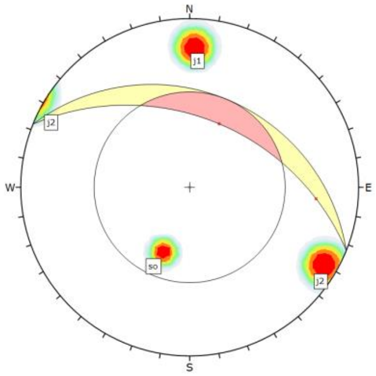

Fig. 11: wedege sliding in station 1

Color	Density Concentrations
	0.00 - 3.40
	3.40 - 6.80
	6.80 - 10.20
	10.20 - 13.60
	13.60 - 17.00
	17.00 - 20.40
	20.40 - 23.80
	23.80 - 27.20
	27.20 - 30.60
	30.60 - 34.00
Maximum Density	33.09%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	45		
Slope Dip Direction	22		
Friction Angle	31°		
Lateral Limits	30°		
	Critical	**Total**	**%**
Flexural Toppling (All)	1	3	33.33%

Plot Mode	Pole Vectors
Vector Count	3 (3 Entries)
Hemisphere	Lower
Projection	Equal Angle

Fig. 12: The percentage of the flexural toppling in station 1

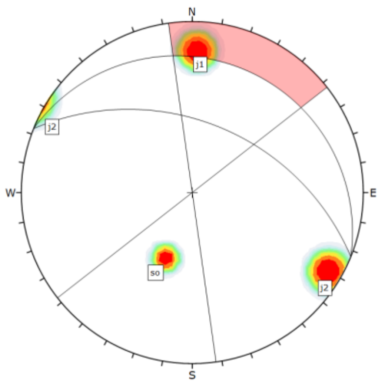

Fig. 13: flexural toppling sliding in station 1

Symbol	Feature
◘	Critical Intersection

Color	Density Concentrations
	0.00 - 3.40
	3.40 - 6.80
	6.80 - 10.20
	10.20 - 13.60
	13.60 - 17.00
	17.00 - 20.40
	20.40 - 23.80
	23.80 - 27.20
	27.20 - 30.60
	30.60 - 34.00
Maximum Density	33.09%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling		
Slope Dip	45		
Slope Dip Direction	22		
Friction Angle	31°		
Lateral Limits	30°		
	Critical	**Total**	**%**
Direct Toppling (Intersection)	1	3	33.33%
Oblique Toppling (Intersection)	0	3	0.00%
Base Plane (All)	1	3	33.33%

Plot Mode	Pole Vectors
Vector Count	3 (3 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	3
Hemisphere	Lower
Projection	Equal Angle

Fig. 14: The percentage of the direct toppling in station 1

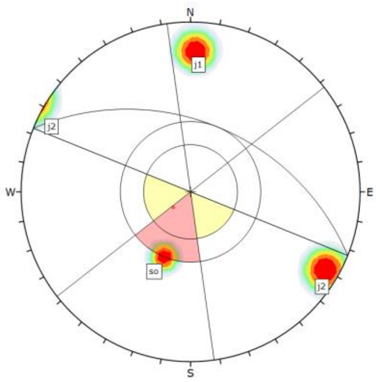

Fig. 15: direct toppling in station 1

• **Station No. (2):** This station is located in the northeastern limb of the Safin anticline, to the right of the street within the Shiranish formation, within the following coordinates: (X=449363), (Y=4019886), and elevation above sea level (Elv=1065 m) in UTM units, which were determined by the (GPS). The station consists of a slope whose attitude is (62/018), with a height of (9 m) and width (50 m).There are four sets of discontinuities, the first group (set1) and its attitude (75/116) and the distance between the discontinuities (frequency = 4 per meter) and represents a release surface, while the second group (set2) and its attitude (67/265) and the distance between the discontinuities (frequency = 4 per meter) and represents a back sliding surface and the third group (set3) and its attitude in the same position with the bedding plane (ab), Concordant with it,and the fourth group (set4) and its attitude (50/190) and the distance between the discontinuities (frequency = 4 per meter).The results of the kinematic analysis of station No. (2): (A) there is a possibility of a planar sliding (25%), (B) there is a possibility of a wedge sliding (16.67%), (C) there is no possibility of a flexural toppling, (D) There is a possibility of a direct toppling (50 %), where (SF) the face of the slope, (SO) the bedding plane (J1, J2), the sums of the discontinuities.

The potential failures resulting from the program are similar to some field data that represent the failure that actually occurred, such as planar sliding, wedge sliding and toppling.

• **Station No. (3):** This station is located in the northeastern limb of the Safin anticline, to the right of the street within the Shiranish formation, within the following coordinates: (X=450057), (Y=4018809), and elevation above sea level (Elv=1093 m) in UTM units, which were determined by the (GPS). The station consists of a slope whose attitude is (30/034), with a height of(15-18 m) and width (50 m).There are three sets of discontinuities, the first group (set1) and its attitude (80/118) and the distance between the discontinuities (frequency = 4 per meter) and represents a release surface, while the second group (set2) and its attitude (75/012) and the distance between the discontinuities (frequency = 4 per meter) and represents a back sliding surface and the third group (set3) and its attitude in the same position with the bedding plane (ab), Concordant with it.The results of the kinematic analysis of station No. (3: (A) there is no possibility of a planar sliding, (B) there is no possibility of a wedge sliding (C) there is no possibility of a flexural toppling (D) There is no possibility of a direct toppling ,where (SF) the face of the slope, (SO) the bedding plane (J1, J2), the sums of the discontinuities.

The potential failures resulting from the program are no similarity to field data that represent the failure that actually occurred.

• **Station No. (4):** This station is located in the southeast limb of the Safin anticline, to the right of the street within the Qamchuqa formation, within the following coordinates: (X=449798), (Y=4018530), and elevation above sea level (Elv=1202 m) in UTM units, which were determined by the (GPS). The station consists of a slope whose attitude is (20/018), with a height of(10 m) and width (70 m).There are tow sets of discontinuities, the first group (set1) and its attitude (88/344) and the distance between the discontinuities (frequency = 4 per meter) and represents a release surface, while the second group (set2) and its attitude (85/081) and the distance between the discontinuities (frequency = 4 per meter) and represents a back sliding surface.The results of the kinematic analysis of station No. (4): (A) there is no possibility of a planar sliding, (B) there is no possibility of a wedge sliding (C) there is no possibility of a flexural toppling (D) There is no possibility of a direct toppling ,where (SF) the face of the slope, (SO) the bedding plane (J1, J2), the sums of the discontinuities.

The potential failures resulting from the program are no similarity to field data that represent the failure that actually occurred.

• **Station No. (5):**

This station is located in the Southwest limb of the Safin anticline, to the left of the street within the Qamchuqa formation, within the following coordinates: (X=448975), (Y=4018240), and elevation above sea level (Elv=1375 m) in UTM units, which were determined by the (GPS). The station consists of a slope whose attitude is (16/000), with a height of(8 m) and width (60 m).There are three sets of discontinuities, the first group (set1) and its attitude (57/160) and the distance between the discontinuities (frequency = 3 per meter) and represents a release surface, while the second group (set2) and its attitude (82/222) and the distance between the discontinuities (frequency = 3 per meter) and represents a back sliding surface and the third group (set3) and its attitude in the same position with the bedding plane (ab), Concordant with it,.The results of the kinematic analysis of station No. (5): (A) there is no possibility of a planar sliding, (B) there is no possibility of a wedge sliding (C) there is no possibility of a flexural toppling (D) There is no possibility of a direct toppling ,where (SF) the face of the slope, (SO) the bedding plane (J1, J2), the sums of the discontinuities.

The potential failures resulting from the program are no similarity to field data that represent the failure that actually occurred.

• **Station No. (6):**

This station is located approximately in the fold axis of the Safin anticline, to the left of the street within the Qamchuqa formation, within the following coordinates: (X=448803), (Y=4018261), and elevation above sea level (Elv=1425 m) in UTM units, which were determined by the (GPS). The station consists of a slope whose attitude is (16/230),with a height of(8-12 m) and width(60 m).There are tow sets of discontinuities, the first group (set1) and its attitude (50/044) and the distance between the discontinuities (frequency = 2 per 1.5 meter) and represents a release surface, while the second group (set2) and its attitude (85/128) and the distance between the discontinuities (frequency = 3 per meter) and represents a back sliding surface.The results of the kinematic analysis of station No. (4): (A) there is no possibility of a planar sliding, (B) there is no possibility of a wedge sliding (C) there is no possibility of a flexural toppling (D) There is no possibility of a direct toppling ,where (SF) the face of the slope, (SO) the bedding plane (J1, J2), the sums of the discontinuities.

The potential failures resulting from the program are no similarity to field data that represent the failure that actually occurred.

Conclusion

The results of the kinematic analysis by DIPS program showed that only Station No. 1 and Station No. 2 have the possibility of failure, and this is due to the operations of cutting rocks from the bottom of the slopes to constructed roads, construct buildings and cultivate lands. And stations 4,5 and 6 have no possibility of failure due to the low slope (less than 20^{O}), as for station No. 3, there is no possibility of failure because the bedding plan is concordant with the rock slope.

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تقييم استقرارية المنحدرات الصخرية على طريق شقلاوة – كويسنجق، شمال شرقي العراق باستخدام التحليل الحركي

سلام صبحي حميد ، أميرة أسماعيل حسين ، عايد حسين ورد

قسم علوم الأرض التطبيقية ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

الملخص

الغرض من الدراسة الحالية تقييم أستقرارية المنحدرات الصخرية على جانبي الطريق الرابط بين (شقلاوة_ كويسنجق) لبعض التكوينات الجيولوجية (قمجوقة،بخمة،شيرانش) المنكشفة ضمن الجناح الشمالي الشرقي aZS لطية سفين المحدبة حيث تم أختيار (6) محطات تم أجراء تصنيف و وصف هندسي للطبقات الصخرية من خلال المسح الشامل لمنطقة الدراسة ،أظهرت نتائج التحليل الحركي بواسطة برنامج (DIPS) إن الأنهيارات المحتملة تمثلت بالانقلاب الصخري بنسبة (83.33%)، الأنزلاق المستوي بنسبة (58.33%) وبعدها الانزلاق الاسفيني بنسبة (83.34%)، من خلال دراسة العـوامل المؤثرة على أستقرارية المنحدرات في المنطقة تبين أن العامل الرئيسي المسبب لحدوث الانهيارات هو نتيجة قطع الطية لغرض شق الطريق أضافة الى العوامل التركيبية والصخارية.