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Studying of rock slope stability for southeastern plunge of Bekhair anticline, North Iraq

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ABSTRACT

The research aims to study rock slope stability for southeastern plunge of Bekhair anticline north Iraq which formations (Bekhme, Shiranish, Kolosh) are cropped out in the area and assessment all factors affecting on stability such as discontinuities. Engineering classification according to[1] and [2], attitude of beds, slopes and friction angle of marl through studying of (4) stations represented the types of failures, occurs or probable to occur. The study shows that the slopes in the area are parallel concordant and discordant while the failures including the main modes of failures such as (Rock fall) in stations (1,3) Toppling in station (4) plane sliding probable in station (2) in addition to rock rolling which sometimes follows the above mentioned modes of failure.

Introduction

Studying and evaluation of the rock slope stability is important studies in engineering geology , and that the great impact in the knowledge of the stability of the mountainous areas because built on them various engineering facilities such as buildings on the slopes, construction of roads, cutting of rocks in the mines, and human activities are the reasons leading to failures [3]. The landslides are environmental disasters that have a major impact on humans and usually occur on mountain slopes when the causative factors are available, and the failures may occur abruptly or may be in several stages or may occur at intervals depending on different factors, such as increasing forces that cause landslides or as well as the structures of rock help to failures, such as joints and fissures. [4] Rock slopes may be very sensitive to any process of disruption of their natural balance, by removing their natural supports or by loading the slopes. The impact of the force of the earth is one of the main factors of the process of sliding on the rock blocks or soil forming the slope sometimes.

1 - Location of Study Area

The study area is located in the north of Iraq near the center of Dohuk governorate and defined by geographical coordinates longitudinal lines (43º 20' 0″- 43º 52′ 0″) and latitude (36º 40′ 0"_ 36º 54′ 40″), in south-eastern of plunge Bikhiar anticline (Fig. 1).

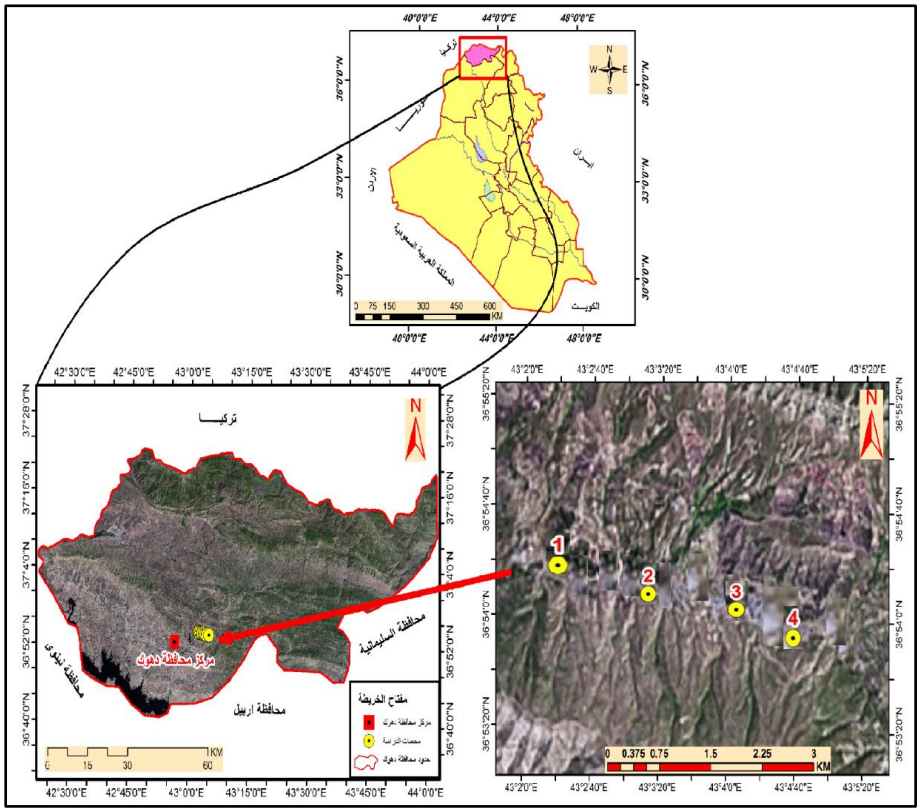

Fig. 1: Map of the study area with locations of the studied stations.

2. Stratigraphy of the Study Area

2.1 Bekhme Formation

The age of this formation is Late Campianian-Early Mastrichtian. It appears in the study area in layers of dolomitic limestone, with light brown or brown color, which contains a chert, alternating with the marl and marly limestone. Bekhma Formation is represents core of Bikhiare fold by a hard layer that is exposed at a height of (1100m) above sea level, represented by the dome (Spiris), thickness of this formation in the study area is (210m), Bekhme Formation contains veins of iron oxides[5] .

2.2 Shiranish Formation

The age of this formation is Late Campanian-Mastrichtian, Shiranish. It represents the low parts of the Spiris anticline, which surrounds Bakhme Formation and its thickness is ranging between (50-100)m. Shiranish Formation is shown in the study area with successive layers of light green marl with layers of light grey medium- to the high hardness and contains sets of fractures. The lower and upper contact of Shiranish Formation is unconformable with Bakhme and Kolosh Formations respectively where there is a layer of limestone with thickness (40cm). In general both parts are widely seen in study area [5].

2.3 Kolosh Formation

The age of this formation is Early Paleocene- Early Eocene, it is composed of non-solid clastic deposits of dark to light grey, and contains thin light brown layers, varying in thickness from shale, limestone, slit, sandstone. These layers also contain rock fragments and various types of minerals. The lower contact of the Kolosh Formation is unconformity with Shiranish Formation, whereas upper contact is Kuramala Formation that also determined by unconformity form [5].

3. Structure and Tectonic of the Study Area

Tectonically, Iraq divided into three main parts[6], which represent the thrust zones, followed by the middle zone, and finally the plane zone. Bolton was adopted in the division on the stratigraphic, structural and geomorphological characteristics. The area of the study is tectonically located within the high folded zone. From the structural side, it is anticline fold belong to the direction of Zagros (northwest-southeast) in Dohuk and Taurus direction (East-West) in Zakho, the Bikhair fold is one of the large in Foreland zone.

4. Geomorphology of the Study Area

Geomorphology study of the region is one of the important studies for the purpose of identifying the landforms and surface phenomena of this region. It was noticed in the field the valleys of "consequent type" and valleys of the type (subsequent), as well as the presence of talus phenomenon, where erosion products were observed below the slopes. The drainage patterns observed in the field are dendritic drainage, and the study area is considered a bad land.

5. Methodology

5.1 Data Collection Stage

In this stage, all information about the study area were collected through researches and reports were used during the field work stage, and maps with scale (1: 25000) and (1: 100,000), as well as the use of satalite images of the region, which have helped to identify many different geological features.

5.2. Field Work Stage

Field work was carried out in several stages. The first included an exploratory tour of the area to identify the geological, of the area and identify the stations where the failures occurred. The second included a detailed engineering geological survey of the failures in the region, as follows:

1 - Location the station by means of a device, (GPS), with UTM units

2 - Determination the station position relative to the limb in which it is located.

3 - Determination attitude of the slope and the beds, such as the value of direction dip / dip angle, the direction of dip is written to the left and the angle of dip is written to the right (030/35). As for slope Over Hanging symbolized by(OH) Example (200/OH), either the rock masses symbolized by (RM).

4 - Measurement the width and height of the slope by tape.

5 - Description the lithology of area, where the rocks are described according to, [1] and [7] also described the rock, according to [2].

6 - Determination the type of failures (plane sliding, rockfall, toppling..... etc) depending on the relationship between attitude of the layers and attitude of the slope.

7 - Determination the type of slope, depending on the relationship between strike of bed and strike of slope, as well as the emergence strike of slope, for the person standing in front of the slope.

8 - Conduct a detailed survey of the discontinuities, including types, attitude (angles & direction), frequency, Persistence on the bedding Surface, and Aperture.

9 - Collection of rock samples representative of the study area from each station, for the purpose of study and conduct all the necessary laboratory tests.

10 - Taking photographs for each station.

5.3 Laboratory Work Stage

The laboratory work was carried out to conduct some geotechnical tests of rocks and soil include the following procedure:

5.3.1. Some geotechnical tests for rocks

Unconfined Compressive Strength:

The compressive strength of the rock is defined as the relationship between the inner strength of the rock and the external force exerted vertically on it. And represent by Rock resistance to vertical pressure is at Failure point. The compressive resistance is influenced by several factors including mineral composion, water content, rate of loading [8], which is one of the simplest mechanical tests of rocks and uses its results in the selection of the appropriate drilling technique, as well as used in the classification of rocks and the study of properties and also in the designs of various engineering projects [9]. The rock samples were formed by core drills by making samples cylindrical and vertical on the direction of bedding in the rate of length to diameter (2:1) and (1: 1), according to standard [10] and by using a compression device (CYBER-PLUS EVOLUTION), which provides a force of (1500 kN) maximum and accurately (0.1 kN). The load is increased by 0.75 N / mm2 / sec, the sample Failure within 5-10 minutes [11]. The test method is to place the sample between the two rates, The sample is subjected to a vertical load and the resulting stress at the moment of Failure is called Unconfined Compressive Strength. The compressive strength of the normal state has been examined according to [7].

Table 1: shows the values of the unconfining compressive strength of limestone and marly limestone samples in their natural state and classification according to [7].

classification according to [7]	Average correct compressive strength C_C Mpa	correct unconfining compressive strength C_C Mpa	unconfining compressive strength C(Mpa)σ	Force fialure F(KN)	D/L	Diameter of samples D (cm)	Length of samples L (cm)	Station no.	Lithology
Moderately strong	32.69	33.70	30.06	66.30	0.514	5.3	10.3	1))a	**Limestone**
		33.71	30.88	68.12	0.623	5.3	8.5	1)) b	
		30.67	27.82	61.35	0.582	5.3	9.1	1))c	
Moderately strong	30.08	31.00	29.05	64.06	0.716	5.3	7.4	2))a	
		29.86	27.17	59.93	0.595	5.3	8.9	2)) b	
		29.39	27.17	61.12	0.746	5.3	7.1	(2)c	
Moderately strong	26.01	24.71	21.97	48.45	0.5	5.3	10.6	(3)a	
		28.18	25.19	55.55	0.524	5.3	6.4	(3)b	
		25.13	24.15	53.26	0.828	5.3	9.1	(3)c	
Moderately strong	31.21	31.48	29.06	64.08	0.654	5.3	8.1	(4)a	Marly limstone
		33.59	30.57	67.41	0.595	5.3	8.9	(4)b	
		28.55	27.89	61.52	0.898	5.3	5.9	(4)c	

5.3.2 Mechanical Properties for soil

Direct Shear Test: This test Considered from Important engineering tests for soil, including measurement of Shear Strength of silt, to find the cohesion (C) and angle of internal friction (Ø), this test was done according to ASTM [12]. Since the sample test were disturbed sample, the samples were prepared after taking a certain weight from the (Marl) and adding the water by (8-10%) of the weight of the sample to facilitate the process of compaction or compression) In the shear mold. There were three parts for each sample and under different weights (2kgm), (4kgm) and (8kgm), respectively. and the shear stress was recorded after the failure of each sample and The results were then obtained. The relationship between the three normal stresses (σ) and the shear stresses (τ) of the sample was plotted, where the relationship was represented in a straight line and the slope of the line with the vertical stress axis (σ) is the value of the angle of the internal friction (Ø) The straight line with the shear stress axis (τ) represents the cohesion value (c), as in Figure (2).

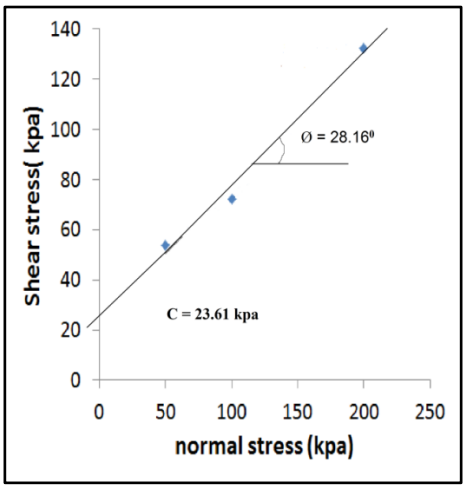

Fig. 2: represents the relationship between the normal stress and Shear stress of the values obtained from the shear test of the station sample (2).

5.4 Office Work Stage

Work done in this stage representation information and field measurements (strike direction, dip direction and dip value) were analyzed by the schmidt net (equal area net) for stereographic Projection, for attitude of bedding and the slope surface and joints sets in each station, to classify the rock slopes according to the relationship between strike of bedding and strike of slope and according to classification of [13].

6. **Types of Failures**

The falls that occur on the rock slopes can be classified based on the type of motion [8], into several types 1 - rock fall 2 -plane sliding 3 - toppling 4 - rolling 5 - flow .

7. Assessment of Rock Slopes Stability in the Study Area

Studying (4) stations distributed on the exposed formations (Bekhme, Shiranish and Kolosh) and analyzed in detail, as well as the study of all the factors that affect them. This is done after a comprehensive survey of the failures in the study area by measuring slope attitude and the layers, the type of slope is determined depending on the angle between strike of the slope and bed. If the angle value ranges from 0-20, the slope is parallel type. and the slope is oblique lateral when angle value ranges from (21º-70º), and orthogonal when angle range between (71-90). As developed [13] several symbols are also used to represent the types of failures on stereonet scheme as in Table (2) and types of poles and great circles used for representing field data on stereographic net scheme as in Table (3).

Table 2: illustrates the symbols used to represent the types of landslides on a chart, the stereonet projection, modified of [13].

Type of failures	Symbols	
	Happen	Probable
plane sliding		
Toppling		
Rock fall		
Rolling		
Oblique lateral failure		
Photo direction		

Table 3: shows the types, poles, and great circles used to represent the field information on the scheme of the stereonet projection of [13].

Terms	Symbol
Pole of bedding plane (So)	+
Pole of joint Plane (St)	•
Cyclographic trace of a general slope (gs)	gs
Cycloraphic trace of silde slope (ss)	ss
Cyclographic trace of Vertical slope (vs) or overhanging slope (OH)	Vs Or OH
Cyclographic trace of the mean orientation of bedding planes (S0)	so
Friction angelØcircle with Area of potential Sliding	Ø A

Station No. (1)

This station is located in the north-west plunge of Spiris dome in Bekhair anticline within Bekhme Formation (figure .1) Plate (1).

The location station was identified by the GPS device, and with UTM units, and the coordinates of longitude (X = 325283) and latitude (Y = 4086183).

This station consists of a slope of 3 m in height from toe, and the length of the face towards strike is (12 m), its attitude (324/72º-OH), parallel slope (d = 1o) the attitude of limestone bedding in this station is (º 325/º29),(figure .2).

Which have the following characteristics light color gray, thick bedded, with moderately strong compressive strength (σc= 32.69 MPa) the slightly weathering SW.

The limestone layer is contain two set of joints (Fig. 2), the first set (ST.1) pe (hko> a) the spacing between the joints ranges from 35-40 cm and thus has moderately wide spaced, their persistence (50 cm) on bedding plane, open in some parts for a distance (2 cm), filled with the quatrnary deposit that covering the slope and its attitude (º212/º79).

The second set (ST.2) (hko> b) the spacing between the joints ranges from (15-25 cm) and thus has moderately wide spaced its persistence up to (20 cm) on the bedding plane, closed, and its attitude (º126/65 °).

The slope is formed the result of the road cut, the type of failure is rock fall due to the presence of hanging parts of the slope and the cohesion through the discontinuity equal(zero).

and failure of the same type is likely to occur when the cohesion become zero, where conditions are available for rockfall except for cohesion through discontinuities.

plate 1: Front view of station No. (1), show the discontinuities in the rock blocks, the direction of the photograph (south-east).

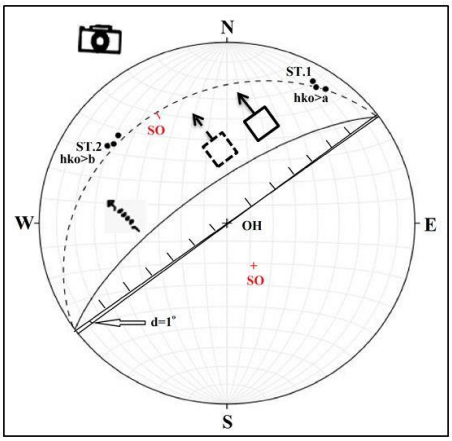

Fig. 2: daigram showing the relationship between the slope and the layers and discontinuities, as well as the failures types of station No. (1) direction of photography (south-east).

Station No. (2)

This station is located in the north-west plunge of Spiris dome in Bekhair fold within Shiranish Formation of the figure (1) Plate (2).

This station was located by the GPS device, and with UTM units, and the coordinates of Longitude (X=325537) and Latitude (Y=4085948).

This station consists of a slope of 7.32m in height from toe, and the length of the face towards strike (23 m), its attitude (341/61º-OH), parallel slope there are (d = 4°) and attitude of bedding in this station is (º 345/º31), figure (3).

expose A very thick layer of limestone in upper part of slope up to (4 m) very fine grains, light yellow color, slightly weathering SW, compressive strength (σc =30.08 MPa) Moderately strong and the lower part of the slope consists of thickly bedded of marl (1.5 m) light gray color, moderately strong compressive strength, fine grains, and high weathering (HW).

The limestone layers cutting by two set of joints , In addition to bedding plane fig (3), the first set (ST.1). (hko> b) The spacing between joints ranges from 20-30 cm moderately wide, with persistence ranging from 0.5 to 1 m on the of bedding planes, closed, and attitude (º133/º68).

The second set (ST.2) (hko> a), with spacing ranging between 35-40 cm. Moderately widely spaced and its persistence are up to 2 m on the bedding plane, Aperture 2 cm and filled with sediments above the slope, and their attitude (215/70 °).

The slope is form result of cutting operations become of instability in the face of the slope. The probability of Failure is of plane sliding when the cohesion across the discontinuities (zero) and the slope angle is higher than the dip of the layer. The stability of this type of slope depends on the angle of internal friction (Ø) and the value of the cohesion (C) of marl, The results showed that the internal friction angle (Ø) (º28.16) and the cohesion value C = 23.611 Kpa since the internal friction angle is less than the angle of the layers, the probable Failure is of plane sliding type.

The discontinuities (ST.1hko> b) play the role of back release surfaces, and the discontinuities (ST.2hko> a) are lateral release surfaces.

plate 2: Front view of station No. (2) Direction of photography (South – East)

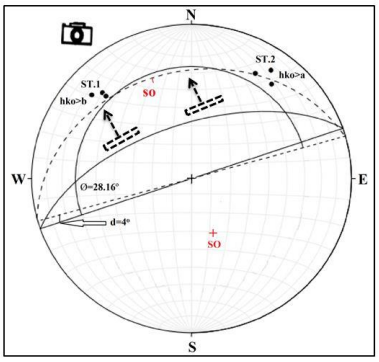

Fig. 3: diagram showing the relationship between the slope and the bedding and discontinuities, as well as the probable failures of station No. (2) direction of photography (south-east)

Station No. (3)

This station is located in the north-west plunge of Spiris dome in Bekhair fold within Bekhme formation of the figure (1) Plate (3).

This station was located by the GPS device, and with UTM units, and the coordinates of longitude (X=328347) and latitude (Y=4085589).

This station consists of a slope of 8m in height from toe, and the length of the face towards strike (75 m), its attitude (016/23-OH), parallel slope (d = 7°) and attitude of bedding in this station is (º28 / º 009), figure (4).

There are a very thicklay bedded of limestone exposed on face of slope with thickness (7 m) light Brown colored, very fine graines, moderately strong compressive strength (σc =26.01Mpa) and slightly weathering SW.

The limestone layers cutting by two set of joints (Figure 4), the first (ST.1), (hko> a), The spacing between discontinuities ranges from 20-50 cm and thus moderately widely spaced persistence about 1.5 m on the of the bedding plane, and have closed joints, and attitude (º 125/º80).

The second set of joints (ST.2) is of the type (hko> b), with spacing ranging from 20-70 cm. It has widely spacing - moderately wide, closed joints , and their attitude (º206/66).

The slope is form result of cutting operations resulting day lighting bedding plane, the type of failures rock fall, due to presence of hanging slope. The possibility of other failures of the same type when the slope face exposed to the processes of weathering and erosion in the lower parts of the slope, which leads to the removal support of limestone in the face of the slope and when the cohesion through the discontinuities (zero), this will lead to the failures of the type of rockfall in the direction of the street.

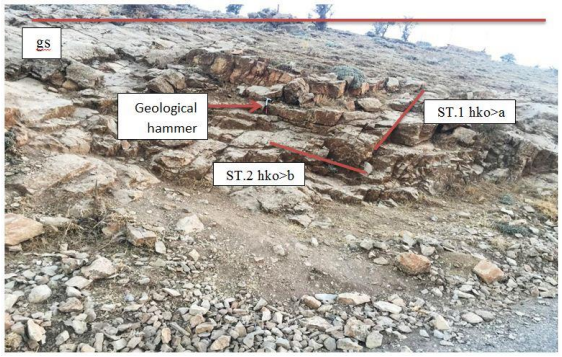

plate 3: Front view of Station No. (3) Direction of Photography South - West.

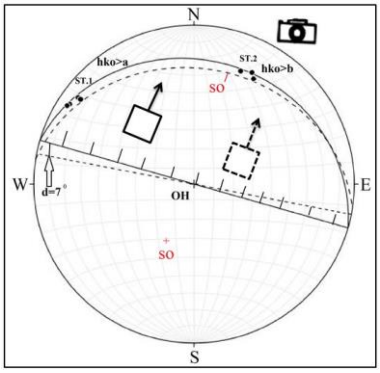

Fig. 4: diagram showing the relationship between the slope and bedding plane and discontinuities, as well as the probable failures type of station (3) direction of photography (south-west).

Station No. (4)

This station is located in the southeast plunge of Spiris dome in Bekhair fold within Kolosh Formation of the figure (1) Plate (4).

This station was located by the GPS device, and with UTM units, and the coordinates of longitude (X=329282) and latitude (Y=4085366).

This station consists of a slope 12 m in height from toe, and the length of the face towards strike (30 m), its attitude (003/72º), parallel type (d = 10°) and attitude of bedding in this station is (º 193/º18), figure (5).

Three groups of rock layers, from top to bottom, are exposed in the face of the slope. The first group is a very thick sandstone layer of thickness (5 m), with light yellow color, medium-fine grains, low compressive strength, highly weathering (HW).

The second group of strata is a very thickly bedded of claystone with thickness (2.5 m), light gray, fine

grains, and moderetaly strong compressive strength (σc= 31.21Mpa), slightly weathering (SW).
The third group of layers is a bed silty sandstone about 4.5 m thick, light green, medium grains, low compressive strength and high weathering (HW).
The rock layers are cutting by three sets of joints (Figure 5), the first (ST.1), hko> b,widely spaced-moderately widely spaced the spacing ranges from (0.50-1m), with persistence about (1.5 m) on the bedding plane, and in aperture some parts are open and reach a (3 cm), and their attitude (56º/º79).
The second set of joints (ST.2), hko>b, the spacing up to 40 cm, which is moderately wide, with persistence of up to 50 cm on the bedding plane and are closed joints , and their attitude (º333/º73)
The third set (ST.3) is joints of the type bc . The spacing between the joints is ranging 15-25 cm. It is therefore widely spaced-slightly , with persistence of up to 30 cm on the bedding plane and are closed joints , And their attitude (º11/º72).
The slope is form result of cutting operations in the appearance of the bedding plane, there is a failures of the toppling is occurred to likely occurred where conditions are including the cohesion through the discontinuities (zero), the direction dip of the slope opposite the direction dip of the layers and the weight of the center of mass outside the support base, led to some of the rock blocks hanging due to erosion and weathering, which got the layers of silty sandstone located below the mass, which led to the toppling to the street. Other failures of the same type (toppling) are likely to occurred when the cohesion through the discontinuities (zero)

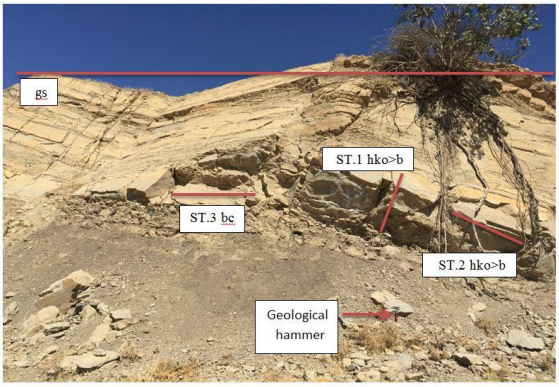

Plate 4: Front view of Station No. (4) Direction of Photography South - West.

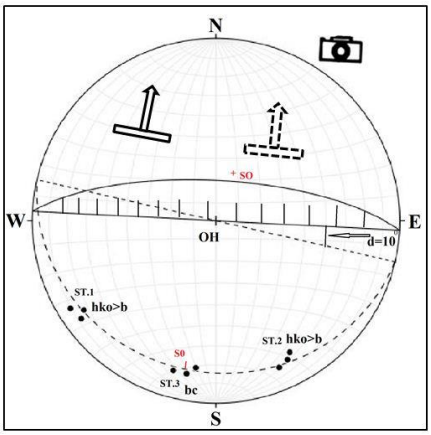

Fig. 5: diagram showing the relationship between the slope and the layers and discontinuities, as well as the possible collapse type of station (4) direction of photography (south-west).

Conclusions

1. The sites of instability concentrated in adjacent areas in study area.
2. slope types in the area are from parallel type concordant and discordant
3.The occurred and likely to occurred failures dominant in the area are rock fall, toppling and plane sliding.
4.The occurrence of rock fall failures because presence of hanging slopes resulting from differential weathering in the study area and presence of discontinuities and when cohesion become zero through discontinuities the failures occurs.
5. The occurrence of toppling failure because presence of vertical or hanging slopes and dip direction of beds revers of slope direction, appropriate geometrical slope and when cohesion become zero and exit gravity center outside the base failure occurs.
6. The probability of occurrence plane sliding failure because presence of weakness marl under limestone rocks and the internal fraction angle of marl less than dip amount of limestone beds in addition the slope is parallel type and amount of its dip layer more than amount dip of beds but cohesion through discontinuities does not reach zero value and when cohesion become zero the failure occurs.

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دراسة استقرارية المنحدرات الصخرية للغاطس الجنوبي الشرقي لطية بيخير المحدبة / شمال العراق

محمد راشد عبود ، علي إسماعيل حسن

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

الملخص

يهدف البحث الى دراسة استقراريه المنحدرات الصخرية للغاطس الجنوبي الشرقي لطية بيخير المحدبة شمال العراق للتكاوين (بخمة, شيرانش, كولوش) ومعرفة كافة العوامل المؤثرة على الاستقرارية مثل الانقطاعات وتصنيفها هندسيا وفق [1] و [2], ووضعية الطبقات للمنحدر وزاوية الاحتكاك الداخلي والتماسك للمارل من خلال دراسة اربع محطات وتوضيح انواع الانهيارات الحاصلة او المحتملة, اظهرت الدراسة ان المنحدرات في المنطقة من نوع الموازية والمتوافقة وغير المتوافقة, في حين تضمنت انواع الانهيارات انهيارات رئيسية مثل السقوط الصخري كما في المحطات (1,3) والانقلاب كما في المحطة (4) والانزلاق المستوي المحتمل في المحطة رقم (2) بالإضافة الى احتمالية الدحرجة التي تحدث بإحدى طرق الانهيار المذكورة آنفا.